TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle D-PL-11120-02-00

Report on the performance test of the 42iQ ambient air quality measuring system for NO, NO_2 and NO_x manufactured by Thermo Fisher Scientific

TÜV report: 936/21242986/C
Cologne, 2 October 2018

www.umwelt-tuv.de

tre-service@de.tuv.com

TÜV Rheinland Energy GmbH and its Ambient Air Quality department in particular
is accredited for the following activities:

- Determination of emissions and ambient air quality affected by air pollutants and odorous substances,
- Inspection of correct installation, functionality and calibration of continuous emission monitoring systems including systems for data evaluation and remote monitoring of emissions,
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and air quality as well as electronic data evaluation and remote monitoring systems for emissions
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
- Determination of emissions and ambient air quality affected by noise and vibration, determination of
- sound power levels and noise measurements at wind turbines;

according to EN ISO/IEC 17025.

The accreditation will expire on 10-12-2022 and
covers the scope specified in the annex to certificate D-PL-11120-02-00.

TÜV Rheinland Energy GmbH
D - 51105 Köln, Am Grauen Stein,
Tel: + 49 (0) 221 806-5200, fax: +49 (0) 221 806-1349

Blank page

Deutsche Akkreditierungsstelle
D-PL-11120-02-00

Report on the performance test of the 42iQ ambient air quality measuring system for NO, NO2 and NOx manufactured by Thermo Fisher Scientific

AMS designation: 42iQ

Manufacturer: Thermo Fisher Scientific
27, Forge Parkway
Franklin, MA 02038
USA

Test period: April 2018 to October 2018

Date of report: 2 October 2018

Report Number: 936/21242986/C

Editor: Dipl.-Ing. Martin Schneider
Phone: +49 221 806-1614
martin.schneider@de.tuv.com

Scope of the report:

Report:	124	pages
Manual	124	
Manual	327	pages
Total	451	pages

Blank page

Table of contents

List of tables

List of figures

Blank page

1. Summary and certification proposal

1.1 Summary Overview

Thermo Fisher Scientific commissioned TÜV Rheinland Energy GmbH to carry out performance testing for the 42iQ air quality monitoring system measuring the components NO, NO_2 and NO_x. The test was performed in respect of the following standards and requirements:

- VDI Guideline 4202 part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants of April 2018
- EN 14211: Ambient air – Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, of August 2012

The 42iQ analyser measures the components NO, NO_2 and NO_x using chemiluminescence. This measuring principle conforms to the EU reference method. The tests were performed in a TÜV Rheinland Energy GmbH laboratory and in a three-months field test in Cologne. The measured ranges are indicated below:

Table 1: Measuring ranges tested

Measured components:	measuring range in [µg/m³] [1]	Measuring range in [ppb] or [nmol/mol]
NO	0–1 200	0–962
NO_2	0–500	0–261

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

During performance testing, the AMS met the requirements specified in standard EN 14211 (2012) and VDI 4202, part 1 (2018).

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:

42iQ for NO, NO_2 and NO_x

Manufacturer:

Thermo Fisher Scientific, Franklin, 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	0–1 200	µg/m³
Nitrogen dioxide	0–500	µg/m³

Software version:

Version: 1.6.1.32120

Restrictions

None

Note:

This report on the performance test is available online at www.qal1.de.

Test Report:

TÜV Rheinland Energy GmbH, Cologne

Report no.: 936/21242986/C dated 2 October 2018

1.3 Summary report on test results

Performance criterion	Requirement	Test result	Satis-fied	Page
7 Performance criteria				
7.3 General requirements				
7.3.1 Measured value display	The measuring system shall have an operative measured value display as part of the instrument.	The measuring system has an operative measured value display at the instrument front.	yes	29
7.3.2 Calibration inlet	The measuring system may have a test gas inlet separate from the sample gas inlet.	The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.	yes	30
7.3.3 Easy maintenance	Maintenance should be possible without larger effort, if possible from outside.	Maintenance takes reasonable effort and is possible with standard tools from the outside.	yes	31
7.3.4 Functional check	Particular instruments required to this effect shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.	The tested measuring system does not have internal devices for operating the functional check.	not applicable	32
7.3.5 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	Set-up times and warm-up times have been determined.	yes	33
7.3.6 Instrument design	The instruction manual shall include specifications in this regard.	Specifications made in the instruction manual concerning instrument design are complete and correct.	yes	34
7.3.7 Unintended adjustment	Shall secure measuring system against that.	The measuring system is secured against unintended and unauthorised adjustment of instrument parameters by way of a password.	yes	35
7.3.8 Data output	The output signals shall be provided digitally and/or as analogue signals.	Measured signals are provided as analogue (0–20 mA, 4–20 mA or 0–1 V, 0–10 V) and digital signals (via TCP/IP, RS 232, USB).	yes	36
7.3.9 Digital interface	The digital interface shall allow the transmission of output signals, status signals, and others. Access to the measuring system shall be secured against unauthorised access.	Digital transmission of measured values operates correctly.	yes	37

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
7.3.10 Data transmission protocol	Shall meet the requirements stipulated in Table 1 of VDI Guideline 4202 part 1.	By default, the measuring system comes with an installed Modbus protocol. Measured and status signals are transmitted correctly. Customers of Thermo Fisher Scientific can look up commands on the internet.	yes	38
7.3.11 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/m³ for NO2 and 0–1200 µg/m³ for NO. Supplementary measuring ranges up to 0–20 ppm are possible. The measuring system's upper limit of measurement exceeds the upper limit of the certification range in each case.	yes	39
7.3.12 Negative output signals	May not be suppressed (life zero).	The measuring system also provides negative output signals.	yes	40
7.3.13 Failure in the mains voltage	Uncontrolled emission of operation and calibration gas shall be avoided; instrument parameters shall be secured by buffering against loss; when mains voltage returns, the instrument shall automatically reach the operation mode and start the measurement.	On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	41
7.3.14 Operating states	The measuring system shall allow their control by telemetrically transmitted status signals.	The measuring system provides various ports to ensure comprehensive monitoring and control via an external computer.	yes	42
7.3.15 Switch-over	Switch-over between measurement and functional check and/or calibration shall be possible telemetrically.	In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.	yes	43
7.3.16 Instrument software	Shall be displayed when switched on. Changes affecting instrument functions shall be communicated to the test laboratory.	The instrument's software version is displayed. Software changes are communicated to the test laboratory.	yes	44

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
7.4 Requirements on performance characteristics for testing in the laboratory				
7.4.1 General requirements	The manufacturer's specifications in the instruction manual shall not contradict the results of the performance test.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)	yes	45
7.4.2 Test requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)	yes	46
Section 8.4 provides a summary of the evaluation of performance characteristics determined in the laboratory.				
7.5 Requirements on performance characteristics for testing in the field				
7.5.1 General requirements	Has to comply with the requirements set out in VDI standard 4202-1:2018.	Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)	yes	61
7.5.2 Location for the field test	The monitoring station for the field test is to be chosen according to the requirements of 39. BImSchV such that the expected concentrations of the measured components to be measured correspond to the designated task. The equipment of the monitoring station shall allow the implementation of the field test and shall fulfil all requirements considered to be necessary during measurement planning.	The field test location was selected in compliance with the 39th BImSchV.	yes	62
7.5.3 Test requirements	The measuring systems shall be installed in the monitoring station and, after connecting to the existing or separate sampling system, activated properly. The adjustments of the measuring system shall meet the specifications of the manufacturer. All adjustments are to be documented in the test report.	During the field test, the measuring system was operated and serviced according to the manufacturer's instructions.	yes	63
Section 8.5 provides a summary of the evaluation of performance characteristics determined in the laboratory.				

Performance criterion	Requirement	Test result	Satis-fied	Page
8.4 Procedures for determination of the performance characteristics during the laboratory test according to EN 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 57 s for NO and 57.5 s for NO2. For instrument 2 it was determined at 58 s for NO and 57.5 s for NO2.	yes	71
8.4.4 Short-term drift	The short-term drift at zero must be ≤ 2.0 nmol/mol/12 h. The short-term drift at span level must be ≤ 6.0 nmol/mol/12 h.	For instrument 1 the value for the short-term drift at zero point was -0.12 nmol/mol/12 h, for instrument 2 it was -0.27 nmol/mol/12 h. Short-term drift at reference point was -0.03 nmol/mol/12 h for instrument 1 and 1.14 nmol/mol/12 h for instrument 2.	yes	76
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 3.0 nmol/mol.	For instrument 1 the value for the repeatability standard deviation at zero point was 0.13 nmol/mol, for instrument 2 it was 0.25 nmol/mol. Repeatability standard deviation at reference point was 0.35 nmol/mol for instrument 1 and 0.39 nmol/mol for instrument 2.	yes	80
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. At concentrations above zero, it shall not exceed 4% of the measured value.	The deviation from the linear regression line for instrument 1 is 0.12 nmol/mol at zero point and no more than 1.13% of the target value for concentrations above zero. The deviation from the linear regression line for instrument 2 is -0.36 nmol/mol at zero point and no more than 0.82% of the target value for concentrations above zero.	yes	83
8.4.7 Sensitivity coefficient to sample gas pressure	The sensitivity coefficient to sample gas pressure shall be ≤ 8.0 nmol/mol/kPa.	For instrument 1, the sensitivity coefficient to sample gas pressure is 0.30 nmol/mol/kPa. For instrument 2, the sensitivity coefficient to sample gas pressure is 0.29 nmol/mol/kPa.	yes	88

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
7.1 8.4.8 Sensitivity coefficient to sample gas temperature	The sensitivity coefficient to sample gas temperature shall be ≤ 3.0 µmol/mol/K.	For instrument 1, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K. For instrument 2, the sensitivity coefficient to sample gas temperature is 0.05 nmol/mol/K.	yes	90
8.4.9 Sensitivity coefficient to surrounding temperature	The sensitivity coefficient to surrounding temperature shall be ≤ 3.0 µmol/mol/K.	The sensitivity coefficient to the surrounding temperature bst did not exceed the performance criterion specified at 3.0 nmol/mol/K. For the purpose of uncertainty calculation, the largest value bst is used for both instruments. This would be 0.601 nmol/mol/K for instrument 1 and 0.271 nmol/mol/K for instrument 2.	yes	92
8.4.10 Sensitivity coefficient to electrical voltage	The sensitivity coefficient to electrical voltage shall not exceed 0.30 nmol/mol/V.	At no test item did the sensitivity coefficient to electrical voltage bv exceed the value of 0.3 nmol/mol/V specified in standard EN 14211. For the purpose of uncertainty calculation, the largest bv is used for both instruments. For instrument 1, this is 0.04 nmol/mol/V and for instrument 2 it is 0.00 nmol/mol/V.	yes	95
8.4.11 Interferents	Interferents at zero and at concentration c_t for NO (500 ± 50 nmol/mol). Deviations for interferents H_2O, CO_2 and NH_3 shall not exceed 5.0 nmol/mol.	At zero point the result for the interference were 0.20 nmol/mol (AMS 1) and -0.20 nmol/mol (AMS 2) for H2O, 0.60 nmol/mol (AMS 1) and 0.00 nmol/mol (AMS 2) for CO2 and finally 1.60 nmol/mol (AMS 1) and 1.80 nmol/mol (AMS 2) for NH3. The following results were obtained for the cross-sensitivity at the limit value ct: NO: -0.20 nmol/mol for instrument 1 and -0.60 nmol/mol for instrument 2; H2O: -0.20 nmol/mol for instrument 1 and 0.20 nmol/mol for instrument 2; CO2 and 2.00 nmol/mol for instrument 1 and 2.40 nmol/mol at NH3.	yes	97
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	100

Performance criterion	Requirement	Test result	Satis-fied	Page
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	103
8.4.14 Converter efficiency	The converter efficiency shall be at least 98%.	At a converter efficiency of 98.5%, the performance criterion specified by EN 14211 is fully satisfied.	yes	105
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 2.2 s.	yes	105
8.5 Determination of the performance characteristics during the field test according to EN 14211				
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.	Maximum long-term drift at zero point $Dl_{,z}$ was at 1.20 nmol/mol for instrument 1 and 1.20 nmol/mol for instrument 2. Maximum long-term drift at reference point $Dl_{,s}$ was at 0.24% for instrument 1 and 0.64% for instrument 2.	yes	108
8.5.6 Inspection interval	The period of unattended operation of the AMS shall be at least 2 weeks.	The necessary maintenance tasks determine the period of unattended operation. In essence, these include contamination checks, plausibility checks and checks of potential status/error warnings. The external particle filter needs replacing at the measurement site after having been subjected to dust loading. EN 14211 requires checking of zero and span points at least once every two weeks.	yes	114
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.	The reproducibility standard deviation for NO2 under field conditions was 2.44% as a percentage of the mean value over the three-months field test period. Thus, the requirements of EN 14211 are satisfied.	yes	111
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	115

2. Task Definition

2.1 Nature of the test

Thermo Fisher Scientific commissioned TÜV Rheinland Energy GmbH to submit the 42iQ 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 nitrogen oxide concentrations in ambient air in the following concentration ranges:

Component	Certification range	Unit
Nitrogen monoxide	0–1200	µg/m³
Nitrogen dioxide	0–500	µg/m³

The 42iQ analyser measures the components NO, NO_2 and NO_x using 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: Automated measuring systems for air quality monitoring – Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants, April 2018
- EN 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

3.1 Measuring principle

The 42iQ ambient air quality measuring system 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, NO_2 and NO_x in ambient air.

Figure 1: View of the 42iQ analyser

The measuring principle of the 42iQ analyser relies on the fact that nitrogen oxide (NO) and ozone (O_3) react to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration. Infrared light emission results when NO_2 molecules decay to lower energy states. Specifically:

$$NO + O_3 \rightarrow NO_2 + O_2 + h\nu$$

Nitrogen dioxide (NO_2) must first be transformed into NO before it can be measured using the chemiluminescent reaction. NO_2 is converted to NO by a molybdenum NO_2-to-NO converter heated to about 325 °C.

The ambient air sample is drawn into the 42iQ through the “sample” bulkhead. The sample flows through a capillary, and then to the mode solenoid valve. The solenoid valve routes the sample either straight to the reaction chamber (NO mode) or through the NO_2-to-NO converter and then to the reaction chamber (NO_x mode). The reaction chamber pressure is measured to infer the sample flow Pressure deviations outside of the acceptable range are reported as a fault.

Dry air enters the 42iQ through the permeation dryer, passes through a flow switch, and then through a silent discharge ozonator. The ozonator generates the ozone needed for the chemiluminescent reaction. At the reaction chamber, the ozone reacts with the NO in the sample to produce excited NO_2 molecules. A photomultiplier tube (PMT) housed in a thermoelectric cooler detects the luminescence generated during this reaction. rom the reaction chamber, the exhaust travels through the ozone (O3) converter to the pump, and is released through the vent.

The NO and NO_x concentrations calculated in the NO and NO_x modes are stored in memory. The difference between the concentrations is used to calculate the NO_2 concentration.

The 42iQ outputs NO, NO_2, and NO_x concentrations to the front panel display and the analogue outputs. and also makes the data available over the serial or Ethernet connection.

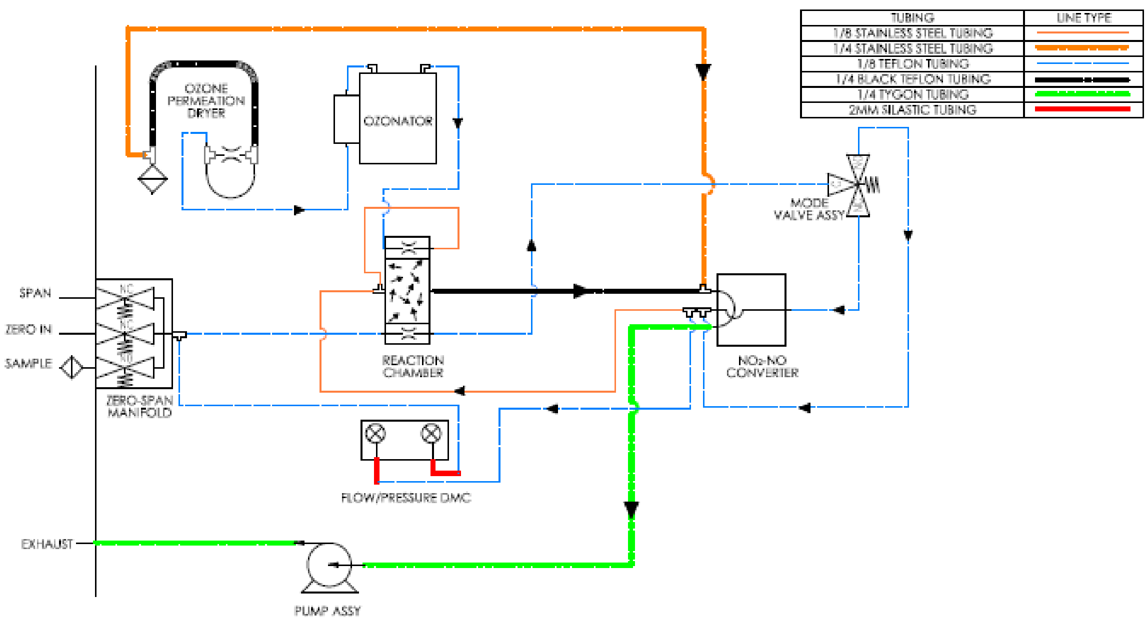


Figure 2: Flow schematic

3.2 AMS scope and set-up

The 42iQ nitrogen oxide analyser uses the chemiluminescent method for the continuous measurement of NO, NO_2 and NO_x in ambient air. The sample to be analysed is led inside the measurement module via an external dust filter. The 49iQ system components include:

- Reaction chamber DMC: The reaction chamber is where the sample reacts with ozone and produces excited NO_2 that gives off a photon of energy when it decays. The reaction chamber is heated and controlled to approximately 50 °C in order to ensure the greatest instrument stability. The sample and ozone flow capillaries and a thermistor sensor are also housed in/on the reaction chamber assembly. The optical filter housed in the reaction chamber limits the spectral region viewed by the detector and eliminates possible interferences due to other chemiluminescent reactions. The Photomultiplier tube (PMT) provides the infrared sensitivity required to detect the NO_2 luminescence resulting from the reaction of the ozone with the ambient air sample. Optical energy from the reaction is converted to an electrical signal by the PMT and sent to the input board that transmits it to the processor. The thermoelectric PMT cooler reduces the PMT temperature to approximately -3 °C to minimize dark current and increase instrument sensitivity.
- Ozone generator: The Ozonator generates the necessary ozone concentration required for the chemiluminescent reaction. The ozone reacts with the NO in the ambient air sample to produce the electronically excited NO_2 molecules.
- Permeation dryer: The permeation dryer provides a continuous stream of dry air to the ozonator.
- NO_2-NO converter: The converter heats molybdenum to approximately 325 °C in order to convert and detect NO_2. The converter consists of an insulated housing, heater, replaceable cartridge, and a type K thermocouple sensor.
- Common electronics: The common electronics contain the core computational and power routing hardware for the 49iQ, and is replicated throughout other iQ series products. It also contains front panel display, the USB ports, the Ethernet port, and the I/O interfaces. All electronics operate from a universal VDC supply. The System Controller Board (SCB) contains the main processor, power supplies, and a sub-processor, and serves as the communication hub for the instrument.
- Peripherals Support System The peripheral support system operates these additional devices that are needed, but do not require special feedback control or processing. The chassis fan provides air cooling of the active electronic components. Internal vacuum pump for generating air/sample through the instrument.
- Flow/Pressure DMC The Flow/Pressure DMC is used measure instrument pressures that assure proper flow regulation and for sample pressure within the measurement bench for pressure corrections and compensation. The DMC includes two pressure sensors.

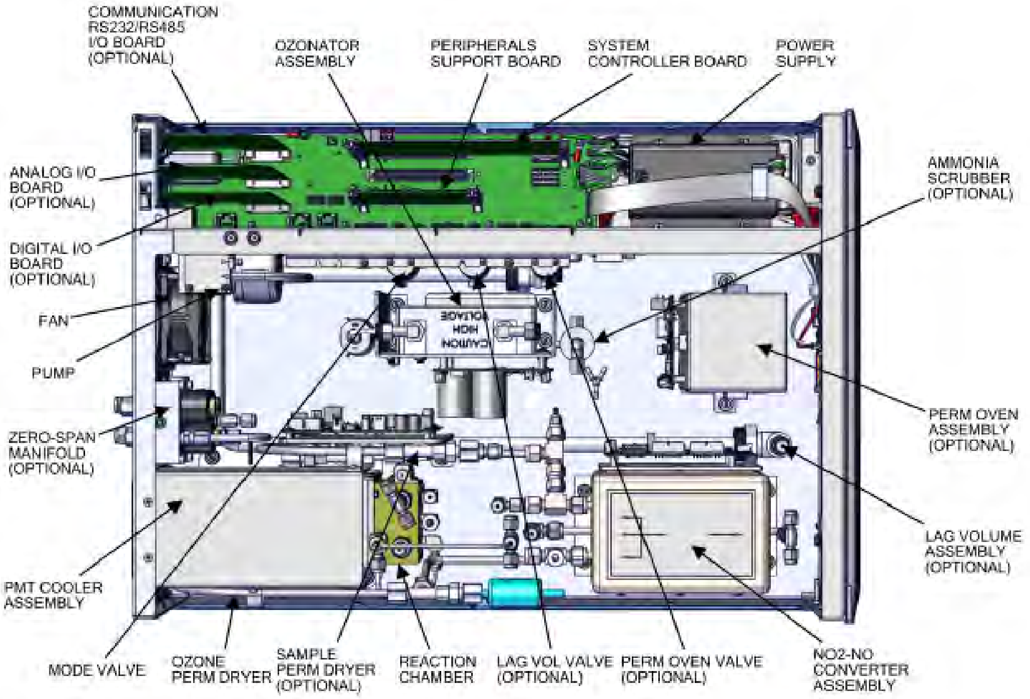


Figure 3: Inside View of the Instrument - Top View

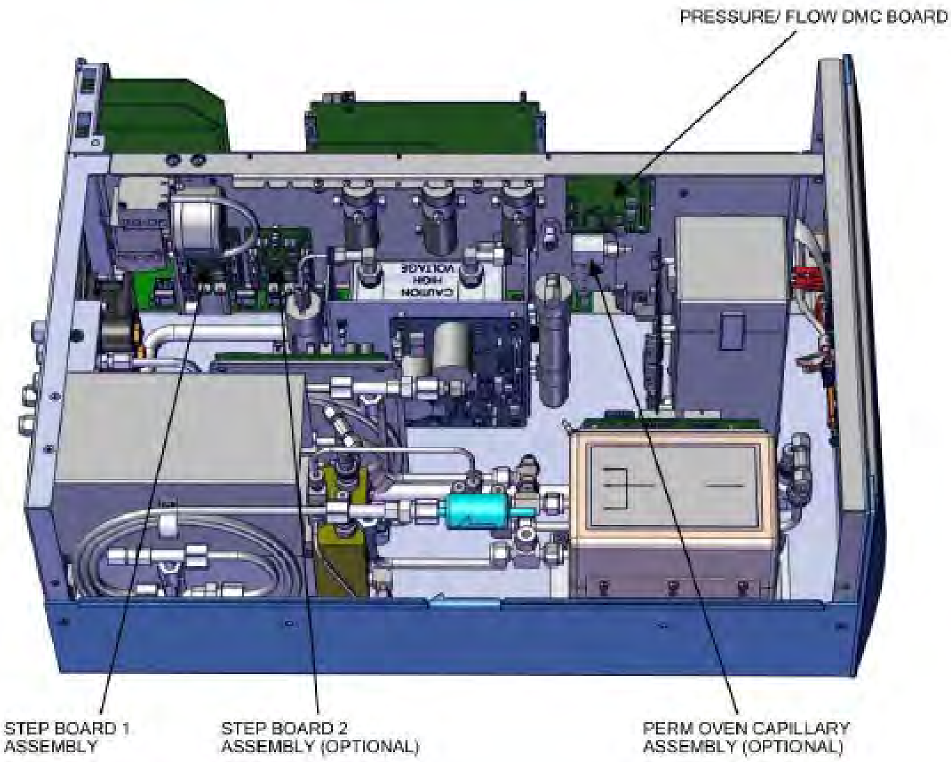


Figure 4: Inside View of the Instrument – Side View

Table 2 lists a number of important instrument characteristics of the 42iQ.

Table 2: Technical Data 42iQ (manufacturer specifications)

Measured range:	Max 0–20 ppm (selectable)
Units:	ppb or µg/m³
Measured compounds:	NO, NO_2 and NO_x
Sample flow rate	~1.0 l/min (during the test)
Outputs:	• USB port (rear) • TCP/IP Ethernet connection • RS232 • Flash memory
Input voltage:	230 V or 115 V 50Hz or 60 Hz
Power:	110 W; 275 W max.
Dimension (l x w x h)	609 x 425 x 221 mm / ~ 10 kg

3.3 AMS adjustment

The measuring system was commissioned according to manufacturer instructions. No internal adjustment cycle was activated during performance testing. Instrument internal averaging time was 60 s.

4. Test programme

4.1 General remarks

Two identical 42iQ instruments with the following serial numbers were submitted to performance testing:

Instrument 1: SN 1180540003 and
Instrument 2: SN 1180540004

The tests were performed with software version „1.6.1.32120“.

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

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

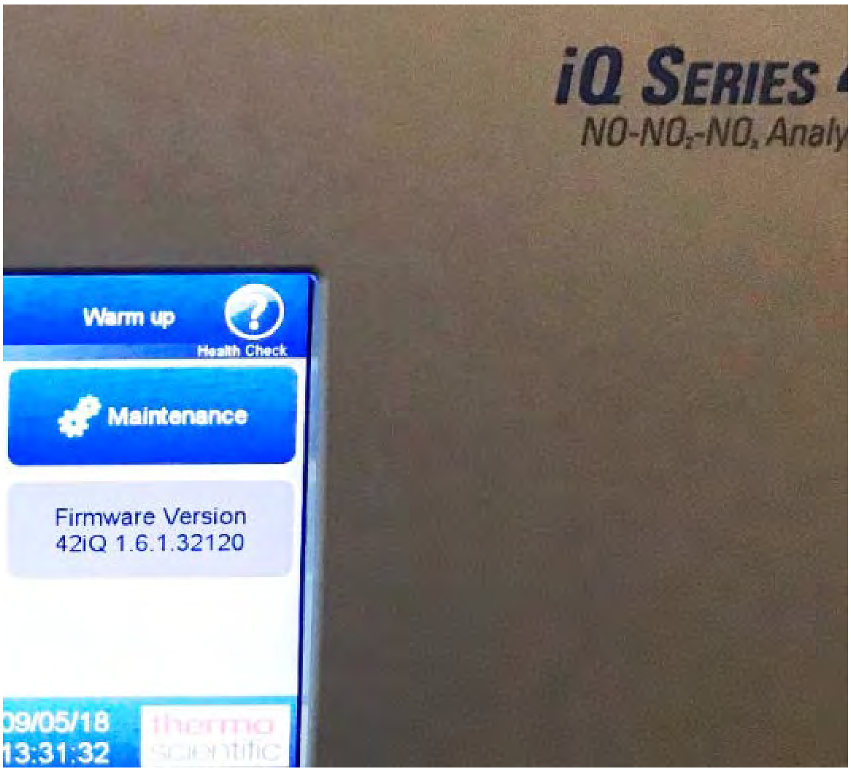


Figure 5: Software version of the tested 42iQ instruments

4.2 Laboratory test

The laboratory test was performed using two complete and identical systems type 42iQ, serial numbers 1180540003 and SN: 1180540004. Standards [1] and [2] specify the following test programme for the laboratory test:

- Description of instrument functions
- General requirements
- Calibration line fit
- 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 effect
- Response time
- Difference sample/calibration inlet
- Converter efficiency

Measured values were recorded using an external data logger.

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

4.3 Field test

The field test was performed between 25/06/2018 and 01/10/2018 using twoidentical 42iQ measuring systems. The instruments used were identical with those used for laboratory testing. The serial numbers were:

instrument 1:	SN 1180540003
instrument 2:	SN 1180540004

The following test programme was determined for the field test:

- Long-term drift
- Period of unattended operation
- Availability
- Reproducibility standard deviation
- Converter efficiency (VDI 4202-1:2018)

Measured values were recorded using an external data logger.

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

5. Reference Measurement Method

5.1 Method of measurement

Test gases used for adjustment purposes during the test

Certified nitrogen monoxide and nitrogen dioxide test gases were used for the purpose of testing. The specified test gases were used during the entire test and, where necessary, were diluted with the help of a (type Hovacal) mass flow controller.

Test gas bottle (S/N 2003890) was traced back by the national EU reference laboratory for ambient air quality (Federal Environment Agency in Langen). Quality assurance of test gases used was based on the traceable test gas in the TRE laboratory.

Zero gas:	**synthetic air**
Test gas NO:	**198.6 ppb in synth. air**
Number of test gas cylinder:	2003890
Manufacturer / date of manufacture:	Linde / 04/07/2018
Stability guarantee / certified:	12 months
Checking of the certificate by / on:	25/07/2018 / UBA Langen Calibration certificate No. 039-2018
Measurement uncertainty as per calibration certificate:	+/- 4.0 nmol/mol
Test gas NO:	**1980 ppb in synth. air**
Number of test gas cylinder:	16462
Manufacturer / date of manufacture:	Praxair / 19/03/2018
Stability guarantee / certified:	24 months
Certificate checked by:	Own laboratory
Rel. uncertainty according to certificate:	5%
Test gas NO_2:	**9.86 ppb ambient 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 4202, part 1 (2018)

6.1 7.3 General requirements

6.1 7.3.1 Measured value display

The measuring system shall have an operative measured value display as part of the instrument.

6.2 Equipment

No additional equipment is required.

6.3 Testing

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

6.4 Evaluation

The measuring system has an operative measured value display at the instrument front.

6.5 Assessment

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

6.6 Detailed presentation of test results

Figure *6* shows the tested AMS with integrated measured value display.

Figure 6: 42iQ test instruments c/w measured value display

6.1 7.3.2 Calibration inlet

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

6.2 Equipment

No additional equipment is required.

6.3 Testing

We tested whether the instrument includes a test gas inlet separate from the sample gas inlet.

6.4 Evaluation

The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.

6.5 Assessment

The measuring system has a test gas inlet separate from the sample gas inlet at the instrument back.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Chapter 7.1 8.4.13 Difference sample/calibration port explains the functionality of the separate sample gas inlet.

6.1 7.3.3 Easy maintenance

Necessary maintenance of the measuring systems should be possible without larger effort, if possible from outside.

6.2 Equipment

No additional equipment is required.

6.3 Testing

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

6.4 Evaluation

The user is advised to perform the following maintenance activities:

1. Checking the operational status
   The operational status may be monitored and checked by visual inspections of the instrument's display or via an external PC connected to the AMS.
2. Checking and replacement of the external 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. All maintenance activities were possible without any difficulties using standard tools.

6.1 7.3.4 Functional check

If the operation or the functional check of the measuring system require particular instruments, they shall be considered as part of the measuring system and be applied in the corresponding sub-tests and included in the assessment.
The performance of test gas generators, which are part of the measuring system, shall be checked by comparing it to the requirements for test gases used for continuous quality assurance. They have to provide a status signal indicating that they are ready for operation. It must be possible to control them directly or remotely.-

6.2 Equipment

Operation manual

6.3 Testing

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

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

6.4 Evaluation

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

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

6.5 Assessment

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

Criterion satisfied? not applicable

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.5 Set-up times and warm-up times

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

6.2 Equipment

Operation manual and additional clock

6.3 Testing

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

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

6.4 Evaluation

The manual does not specify the set-up time. It will of course depend on the situation given at the site of installation as well as the local voltage supply. Since the 42iQ 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).

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

When switching the AMS on in a completely cold state, it takes about 90 minutes to reach a stable reading.

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

6.5 Assessment

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

It is possible to operate the measuring system at different locations with limited effort. Set-up time is 30 minutes and warm-up time ranges between 1 and 2 hours depending on the necessary stabilisation.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.6 Instrument design

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

6.2 Equipment

Operation manual and a measuring system for recording energy consumption (Gossen Metrawatt) and scales.

6.3 Testing

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

6.4 Evaluation

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

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

The manufacturer specifies a maximum power consumption of 275 W. During start-up (warm-up) a short-term consumption of 260 W was recorded. During normal operation, energy consumption is 110 W.

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 7.3.7 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation. Alternatively, the user manual shall specifically note that the measuring system may only be installed in a secured area.

6.2 Equipment

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

6.3 Testing

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

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

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 7.3.8 Data output

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

6.2 Equipment

Analogue Yokogawa data logger, PC

6.3 Testing

The measuring system provides the following transmission routes: Modbus, RS232, RS485, USB, digital outputs, TCP/IP network. Moreover, the measuring system also provides an option to output analogue signals (V or mA).

6.4 Evaluation

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

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

6.5 Assessment

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

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 7.3.9 Digital interface

The digital interface shall allow the transmission of output signals, status signals, and information like instrument type, measurement range, and measured component and unit. The digital interface shall be described fully in respective standards and guidelines.
Access to the measuring system via digital interfaces, e.g. for data transmission, shall be secured against unauthorised access, e.g. by a password.

6.2 Equipment

PC

6.3 Testing

The measuring system provides the following transmission routes: Modbus, RS232, RS485, USB, 10 digital outputs, TCP/IP network. Moreover, the measuring system also provides an option to output analogue signals (V or mA).

6.4 Evaluation

Digital measured signals are provided as follows:

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

Digital output signals were checked. All relevant pieces of information such as measured signals, status signals, measured component, measuring range, unit and instrument information can be transmitted digitally.

Digital data retrieval always requires entry of the correct password.

6.5 Assessment

Digital transmission of measured values operates correctly.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 7.3.10 Data transmission protocol

The measuring system shall contain at minimum one data transmission protocol for the digital transmission of the output signal.
Every data transmission protocol provided by the manufacturer for the measuring system shall allow the correct transmission of the data and detect errors in the transmission. The data transmission protocol including the used commands is to be documented in the instruction manual. The data transmission protocol shall allow to transmit at minimum the following data:
identification of the measuring system
identification of measured components
Unit
output signal with time signature (date and time)
operation and error status
operating commands for remote control of the measuring systems

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

6.2 Equipment

PC

6.3 Testing

By default, the measuring system comes with an installed Modbus protocol.

6.4 Evaluation

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

6.5 Assessment

By default, the measuring system comes with an installed Modbus protocol. Measured and status signals are transmitted correctly. Customers of Thermo Fisher Scientific can look up commands on the internet.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 7.3.11 Measuring range

The upper limit of measurement of the measuring systems shall be greater or equal to the upper limit of the certification range.

6.2 Equipment

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

6.3 Testing

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

6.4 Evaluation

In theory, it is possible to set the measuring system to measuring ranges of up to 0–20 ppm.

Possible measuring range: 20 ppm
Upper limit of the certification range for NO: 1200 µg/m³ (962 ppb or nmol/mol)
Upper limit of the certification range for NO_2: 500 µg/m³ (261 ppb or nmol/mol)

6.5 Assessment

By default, the measuring range is set to 0–500 µg/m³ for NO_2 and 0–1200 µg/m³ for NO. Supplementary measuring ranges up to 0–20 ppm are possible.

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

VDI 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 oxides:

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

Measured components:	CR lower limit	CR upper limit	Limit value	Evaluation period
	in µg/m³	in µg/m³	in µg/m³	
Nitrogen dioxide	0	500	200	1 h
Nitrogen monoxide	0	1 200	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.

6.1 7.3.12 Negative output signals

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

6.2 Equipment

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

6.3 Testing

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

6.4 Evaluation

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 7.3.13 Failure in the mains voltage

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

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 signalled via various temperature alerts.

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 7.3.14 Operating states

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

6.2 Equipment

Computer for data acquisition

6.3 Testing

The measuring system possesses various interfaces such as RS232, USB, digital and analogue inputs and outputs, TCP/IP network. A simple connection can be established between the analyser (42iQ) and an external computer via a web browser. This enables telemetrically transferring data, adjusting configurations and displaying the analyser reading on the computer screen. In this mode it is possible to access and operate all the information and features from the analyser display via the computer. Moreover, “remote operation” provides a useful tool for checking instrument operational and parameter values.

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.15 Switch-over

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.3.16 Instrument software

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

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

The tests were performed with software version "1.6.1. 32120".

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 5 shows the software version displayed by the measuring system.

6.1 7.4 Requirements on performance characteristics for laboratory testing

6.1 7.4.1 General requirements

The performance characteristics which shall be determined during testing in the laboratory and their related performance criteria for measured components according to 39. BImSchV are given in Table A1 of VDI 4202-1.
The certification range for other components is to be defined. Performance criteria are to be defined by drawing from Table A1 of standard VDI 4202-1 (2018). These definitions shall be cleared with the relevant body before testing.
The determination of the performance characteristics shall be done according to the procedures de-scribed in Section 8.4.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211.

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.4.2 Test requirements

Before operating the measuring system, the instruction manual of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable supplies necessary.

The measuring system shall be allowed to warm up for the duration specified by the manufacturer be-fore undertaking any tests. If the warm-up time is not specified, a minimum of 4 h applies.

If auto-scale or self-correction functions are arbitrary, these functions shall be turned off during the laboratory test.

If auto-scale or self-correction functions are not arbitrary but treated as "normal operating conditions", times and values of the self-correction shall be available for the test laboratory. The values of the auto-zero and auto-drift corrections are subject to the same restrictions as given in the performance characteristics.

Before applying test gases to the measuring sys-tem, the test gas system shall have been operated for a sufficiently long time in order to stabilize the concentrations applied to the measuring system. The measuring system shall be tested using an implemented particle filter.

Most measuring systems are able to display the output signal as running average of an adjustable period. Some measuring systems adjust the integration time as a function of the frequency of the fluctuations of the concentration of the measured component automatically. These options are typically used for equalisation of the output data It does not have to be proved that the selected value for the averaging period or the use of an active filter affects the result of testing the averaging period and the response time.

The adjustments of the measuring system shall meet the specifications of the manufacturer. All adjustments are to be documented in the test report.

For the determination of the various performance characteristics, suitable zero and test gases shall be used.

Parameters: During the test for each individual performance characteristic, the values of the following parameters shall be stable within the specified range given in Table 3 of standard VDI 4202-1.

Test gas: For the determination of the various performance characteristics, test gases traceable to national or international standards shall be used.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211.

6.4 Evaluation

The warm-up time described in the manual was observed.

Neither auto-scale nor self-correction functions were activated during the laboratory test.

The system for test gas application ran smoothly; tests were performed with the internal upstream particle filters.

The averaging time was set to 60 s for testing. No equalisation filters were activated.

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

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.4.3 Response time and memory effect

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

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

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

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 7.4.4 Short-term drift

The short-term drift at zero point shall not exceed 2.0 nmol/mol.
The short-term drift at reference point shall not exceed 6.0 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 chapter7.1 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 7.4.5 Repeatability standard deviation

The repeatability standard deviation at zero point shall be ≤ 1.0 nmol/mol of the upper limit of the certification range.
The repeatability standard deviation at reference point shall not exceed 3.0 nmol/mol.

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 REF _Ref350855257 \h 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 7.4.6 Linearity

The analytical function describing the relationship between the measured values and the desired values shall be linear. Reliable linearity is
The deviation from the linearity of the calibration function at zero shall not exceed 5 nmol/mol. At concentrations above zero, it shall not exceed 4% of the measured value.

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the linearity corresponds exactly to determining the lack of fit in accordance with standard EN 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 7.4.7 Sensitivity coefficient to sample gas pressure

The sensitivity coefficient of sample gas pressure at reference point shall not exceed 8.0 (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 7.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient of sample gas temperature shall not exceed 3.0 (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 7.1 8.4.8 Sensitivity coefficient to sample gas temperature.

6.4 Evaluation

See chapter 7.1 8.4.8 Sensitivity coefficient to sample gas temperature

6.5 Assessment

See chapter 7.1 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 7.4.9 Sensitivity coefficient to surrounding temperature

The sensitivity coefficient of surrounding temperature shall not exceed 3.0 (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 chapter7.1 8.4.9 Sensitivity coefficient to surrounding temperature

6.5 Assessment

See chapter7.1 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 7.4.10 Sensitivity coefficient to electrical voltage

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 7.4.11 Cross sensitivity

The change in the measured value caused by interfering components in the sample gas shall not exceed the requirements of Table A of VDI 4202, part 1 (April 2018), at zero and reference point.

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

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating cross sensitivity corresponds exactly to determining interferents in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.4.11 Interferents

6.4 Evaluation

See chapter 7.1 8.4.11 Interferents

6.5 Assessment

See chapter 7.1 8.4.11 Interferents

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.4.12 Averaging effect

The measuring system shall enable hourly averages.

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 7.4.13 Difference between sample and calibration port

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

6.2 Equipment

Not applicable

6.3 Testing

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 7.4.14 Converter efficiency

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

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the converter efficiency in the laboratory 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 7.4.15 Residence time in the analyser

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

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

6.2 Equipment

Not applicable

6.3 Testing

Performing and evaluating the averaging effect corresponds exactly to determining the averaging test in accordance with standard EN 14211 (2012). This is why we refer to Chapter 7.1 8.4.14 Residence time in the analyser.

6.4 Evaluation

See chapter 7.1 8.4.14 Residence time in the analyser

6.5 Assessment

See chapter 7.1 8.4.14

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5 Requirements on performance characteristics for testing in the field

6.1 7.5.1 General requirements

The performance characteristics which shall be determined during testing in the field and their related performance criteria for measured components according to 39. BImSchV are given in Table A1 of VDI 4202-1 (2018).

The certification range for other components is to be defined. Performance criteria are to be defined by drawing from Table A1 of VDI 4202-1 (2018) These definitions shall be cleared with the relevant body before testing.

The determination of the performance characteristics shall be done according to the procedures de-scribed in Section 8.5 of VDI 4202-1 (2018).

6.2 Equipment

Not required for this performance criterion

6.3 Testing

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211.

6.4 Evaluation

Not applicable.

6.5 Assessment

Tests were performed using the performance characteristics specified in VDI standard 4202, part 1 (2018) and standard EN 14211 (2012)

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.2 Location for the field test

The monitoring station for the field test is to be chosen according to the requirements of 39. BImSchV such that the expected concentrations of the measured components to be measured correspond to the designated task. The equipment of the monitoring station shall allow the implementation of the field test and shall fulfil all requirements considered to be necessary during measurement planning.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

The field test location was selected in compliance with the 39th BImSchV. The measuring station for the field test was located at a car park on the premises of TÜV Rheinland.

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.3 Test requirements

The measuring systems shall be installed in the monitoring station and, after connecting to the existing or separate sampling system, activated properly.
The adjustments of the measuring system shall meet the specifications of the manufacturer. All adjustments are to be documented in the test report.
The measuring systems shall be maintained during the field test, following the manufacturer's specifications, and shall be checked with suitable test gases regularly.
If the measuring system contains auto-scale or self-correction functions and they are treated as "normal operating conditions", these functions shall be turned on during the field test. Values of the self-correction shall be available to the test laboratory. The values of the auto-zero and auto-drift corrections for the inspection interval (long-term drift) are subject to the same restrictions as given in the performance characteristics.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

For the purpose of field testing, the measuring system was mounted in a measuring station and connected to the existing sampling system. The measuring system was then commissioned following the manufacturer's instructions in the manual.

Neither self-correction nor auto-zero functions were activated during the field test.

6.4 Evaluation

During the field test, the measuring system was operated and serviced according to the manufacturer's instructions. Neither self-correction nor auto-zero functions were activated.

6.5 Assessment

During the field test, the measuring system was operated and serviced according to the manufacturer's instructions.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 7.5.4 Long-term drift

The long-term drift at zero point shall not exceed 5.0 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 7.1 8.5.4 Long-term drift.

6.4 Evaluation

See chapter 7.1 8.5.4 Long-term drift.

6.5 Assessment

See chapter 7.1 8.5.4 Long-term drift.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.5 Reproducibility standard deviation under field conditions

The standard deviation from paired measurements under field conditions shall be determined with two identical measuring systems by paired measurements in the field test.
The standard deviation under field conditions shall not exceed 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 NO_2 under field conditions.

6.4 Evaluation

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO_2 under field conditions

6.5 Assessment

See chapter 7.1 8.5.5 Reproducibility standard deviation for NO_2 under field conditions
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.6 Inspection interval

The inspection interval of the measuring system shall be determined during the field test and specified. The maintenance interval should be three months, if possible, but at least two weeks.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

Performing and evaluating the inspection interval corresponds exactly to determining the period of unattended operation in accordance with standard EN 14211 (2012). The reader is therefore referred to chapter 7.1 8.5.6 Inspection interval.

6.4 Evaluation

See chapter 7.1 8.5.6 Inspection interval.

6.5 Assessment

See chapter 7.1 8.5.6 Inspection interval.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.7 Availability

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

6.2 Equipment

Not applicable

6.3 Testing

Determination and evaluation of the availability corresponds exactly to determining the period of availability of the analyser in accordance with standard EN 14211 (2012). This is why we refer to Chapter 7.1 8.5.7 Period of availability of the analyser.

6.4 Evaluation

See Chapter 7.1 8.5.7 Period of availability of the analyser

6.5 Assessment

See Chapter 7.1 8.5.7 Period of availability of the analyser

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable in this instance.

6.1 7.5.8 Converter efficiency

At the end of the field test, the converter efficiency shall be at least 95 %.

6.2 Equipment

Test samples, ozonator, NO test gas

6.3 Testing

VDI 4202-1:2018 additionally requires the converter efficiency to tested at the end of the field test. This test was performed following the procedures of EN 14211 for converter efficiency in the laboratory test.

The converter efficiency is determined by measurements with calculated amounts of NO_2. This can be achieved by means of gas-phase titration of NO to NO_2 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 NO_2.

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 O_3 to produce NO_2. 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 O_3 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 NOx channel at the initial NOx 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 O_3;
$(NO)_i$	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 O_3;

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

6.4 Evaluation

During the test, the following converter efficiencies were determined for the two 42iQ measuring systems. The lowest value of the two NO_2 concentration is reported below.

	requirement	device 1		device 2	
converter efficiency E_c [%]	≥ 95%	99.7	✓	98.8	✓

6.5 Assessment

The performance criterion specified by standard VDI 4202-1 (2018) is fully satisfied.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 4 presents the individual values.

Table 4: Individual results for the converter efficiency

				device 1		device 2	
	time	O_3 [nmol/mol]	NO_2 [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]
	13:30:00	start					
O_3=0, NO=50%	13:42:00	0.0	0.1	481.6	484.0	481.6	479.2
	13:43:00	0.0	0.2	481.0	484.0	482.2	479.8
	13:44:00	0.0	0.1	481.6	484.6	482.2	479.8
	13:45:00	0.0	-0.2	482.2	484.6	482.2	479.8
average		0.0	0.0	481.6	484.3	482.1	479.6
NO_2= 50%	14:05:00	135.0	126.4	355.3	484.0	356.5	478.6
	14:06:00	135.0	126.5	355.3	484.6	356.5	478.6
130.75	14:07:00	135.0	126.2	355.9	484.0	355.9	478.6
	14:08:00	135.0	125.6	356.5	484.0	356.5	478.6
average		135.0	126.2	355.8	484.2	356.4	478.6
O_3=0, NO=50%	14:52:00	0.0	-0.2	484.6	487.0	484.6	481.6
	14:53:00	0.0	-0.2	484.0	487.6	485.8	482.2
	14:54:00	0.0	0.0	484.0	487.0	485.8	482.8
	14:55:00	0.0	0.0	484.6	487.6	485.8	482.8
average		0.0	-0.1	484.3	487.3	485.5	482.4
NO_2= 95%	15:15:00	250.0	251.5	232.7	487.0	233.3	479.2
	15:16:00	250.0	251.3	232.7	486.4	233.3	479.2
248.43	15:17:00	250.0	251.3	233.3	486.4	233.3	479.8
	15:18:00	250.0	251.0	233.3	486.4	232.7	479.2
average		250.0	251.3	233.0	486.6	233.1	479.3
O_3=0, NO=50%	15:34:00	0.0	0.1	485.2	488.2	485.8	483.4

6.1 7.6 Type approval and calculation of the measurement uncertainty

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

1) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table C1 of VDI 4202-1 (2018).

2) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory tests shall fulfil the criterion as stated Table C1 of VDI 4202-1 (2018). *This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex F of standard VDI 4202-1 (2018).*

3) The value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table A1 of VDI 4202-1 (2018).

4) The expanded uncertainty calculated from the standard uncertainties due to the values of the specific performance characteristics obtained in the laboratory and field tests shall fulfil the criterion as stated Table C1 of VDI 4202-1 (2018). This criterion is the maximum uncertainty of individual measurements for continuous measurements at the 1-hour limit value. The relevant specific performance characteristics and the calculation procedure are given in Annex F.

6.2 Equipment

Not applicable

6.3 Testing

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

6.4 Evaluation

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

6.5 Assessment

Uncertainty calculation war performed in line with standard EN 14211 (2012) and is presented in 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 Testing

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 fort the dead time (rise) as shown in Figure 7. 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 7 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.

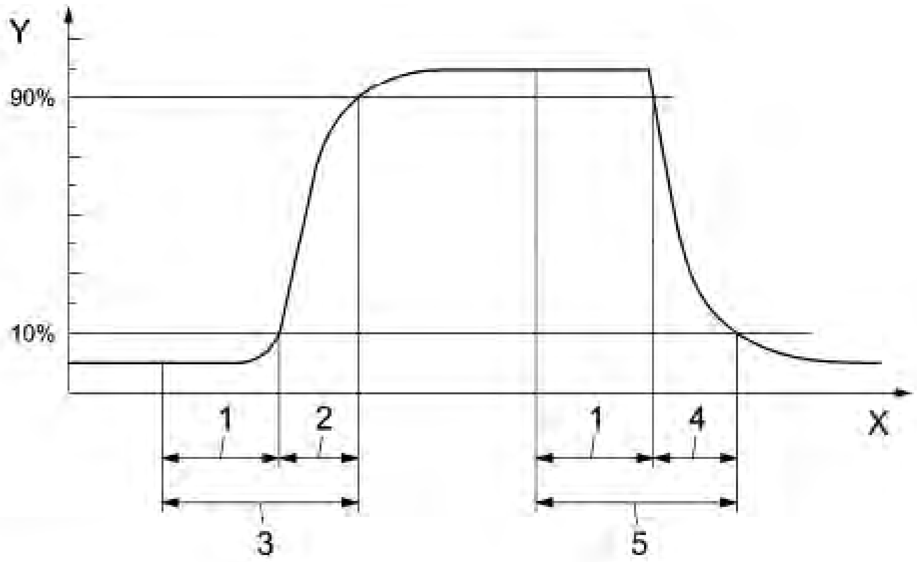
The test shall then be repeated with NO_2 at levels from less than 20 % to about 80 % of the maximum of the certification range of NO_2 and vice versa.

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;
t_r is the response time (rise) (average of the four response times - rise), in s;
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

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

Figure 7: Diagram illustrating the response time

7.3 Testing

The test was performed in line with the requirements of EN 14211 mentioned before. An external data logger was used to record data.

7.4 Evaluation

Table 5: Response times of the two 42iQ measuring systems for NO

	requirement	device 1		device 2	
average rise t_r [s]	≤ 180 s	57	✓	58	✓
average fall t_f [s]	≤ 180 s	57	✓	56	✓
difference t_d [s]	≤ 10 s	0.0	✓	2.0	✓

For NO, system 1, the average t_r was 57 s, the average t_f was 57 s and t_d 0 s.
For NO, system 2, the average t_r was 58 s, the average t_f was 56 s and t_d -2 s.

Table 6: Response times of the two 42iQ measuring systems for NO_2

	requirement	device 1		device 2	
average rise t_r [s]	≤ 180 s	57	✓	57	✓
average fall t_f [s]	≤ 180 s	57.5	✓	57.5	✓
difference t_d [s]	≤ 10 s	-0.5	✓	-0.5	✓

For NO_2, system 1, the average t_r was 57, the average t_f was 57.5 and t_d -0.5s.
For NO_2, system 2, the average t_r was 57, the average t_f was 57.5 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 57 s for NO and 57.5 s for NO_2. For instrument 2 it was determined at 58 s for NO and 57.5 s for NO_2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 7: Individual results of the response time for NO

		device 1					
	80%		rise			fall	
measuring range	768.00	0.0 0.00	0.9 691.20	1.0 768.00	1.0 768.00	0.1 76.80	0.0 0.00
cycle 1	t = 0	08:56:00	08:56:57	08:57:00	09:02:00	09:02:58	09:03:00
	delta t		00:00:57			00:00:58	
	delta t [s]		57			58	
cycle 2	t = 0	09:08:00	09:08:56	09:10:00	09:15:00	09:15:56	09:17:00
	delta t		00:00:56			00:00:56	
	delta t [s]		56			56	
cycle 3	t = 0	09:22:00	09:22:57	09:24:00	09:29:00	09:29:56	09:31:00
	delta t		00:00:57			00:00:56	
	delta t [s]		57			56	
cycle 4	t = 0	09:36:00	09:36:58	09:38:00	09:43:00	09:43:58	09:45:00
	delta t		00:00:58			00:00:58	
	delta t [s]		58			58	

		device 2					
	80%		rise			fall	
measuring range	768.00	0.0 0.00	0.9 691.20	1.0 768.00	1.0 768.00	0.1 76.80	0.0 0.00
cycle 1	t = 0	08:56:00	08:56:59	08:57:00	09:02:00	09:02:58	09:03:00
	delta t		00:00:59			00:00:58	
	delta t [s]		59			58	
cycle 2	t = 0	09:08:00	09:08:57	09:10:00	09:15:00	09:15:54	09:17:00
	delta t		00:00:57			00:00:54	
	delta t [s]		57			54	
cycle 3	t = 0	09:22:00	09:22:59	09:24:00	09:29:00	09:29:58	09:31:00
	delta t		00:00:59			00:00:58	
	delta t [s]		59			58	
cycle 4	t = 0	09:36:00	09:36:57	09:38:00	09:43:00	09:43:54	09:45:00
	delta t		00:00:57			00:00:54	
	delta t [s]		57			54	

Table 8: Individual results of the response time for NO_2

		device 1					
	80%	rise			fall		
measuring range	209.21	0.0 0.00	0.9 188.28	1.0 209.21	1.0 209.21	0.1 20.92	0.0 0.00
cycle 1	t = 0	13:07:00	13:07:58	13:09:00	13:14:00	13:14:57	13:16:00
	delta t		00:00:58			00:00:57	
	delta t [s]		58			57	
cycle 2	t = 0	13:21:00	13:21:56	13:23:00	13:28:00	13:28:57	13:30:00
	delta t		00:00:56			00:00:57	
	delta t [s]		56			57	
cycle 3	t = 0	13:35:00	13:35:57	13:37:00	13:42:00	13:42:58	13:44:00
	delta t		00:00:57			00:00:58	
	delta t [s]		57			58	
cycle 4	t = 0	13:49:00	13:49:57	13:51:00	13:56:00	13:56:58	13:58:00
	delta t		00:00:57			00:00:58	
	delta t [s]		57			58	

		device 2					
	80%	rise			fall		
measuring range	209.21	0.0 0.00	0.9 188.28	1.0 209.21	1.0 209.21	0.1 20.92	0.0 0.00
cycle 1	t = 0	13:07:00	13:08:00	13:09:00	13:14:00	13:14:58	13:16:00
	delta t		00:01:00			00:00:58	
	delta t [s]		60			58	
cycle 2	t = 0	13:21:00	13:21:55	13:23:00	13:28:00	13:28:56	13:30:00
	delta t		00:00:55			00:00:56	
	delta t [s]		55			56	
cycle 3	t = 0	13:35:00	13:35:55	13:37:00	13:42:00	13:42:58	13:44:00
	delta t		00:00:55			00:00:58	
	delta t [s]		55			58	
cycle 4	t = 0	13:49:00	13:49:58	13:51:00	13:56:00	13:56:58	13:58:00
	delta t		00:00:58			00:00:58	
	delta t [s]		58			58	

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 Testing

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	
averange at zero at the beginning [nmol/mol]	-	0.12		-0.33	
averange at zero at the end [nmol/mol]	-	0.00		-0.60	
averange at span at the beginning [nmol/mol]	-	712.45		712.57	
averange at span at the end [nmol/mol]	-	712.30		713.44	
12-hour drift at zero $D_{s,z}$ [nmol/mol]	≤ 2,0	-0.12	✓	-0.27	✓
12-hour drift at span $D_{s,s}$ [nmol/mol]	≤ 6,0	-0.03	✓	1.14	✓

7.5 Assessment

For instrument 1 the value for the short-term drift at zero point was -0.12 nmol/mol/12 h, for instrument 2 it was -0.27 nmol/mol/12 h.

Short-term drift at reference point was -0.03 nmol/mol/12 h for instrument 1 and 1.14 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.

Table 10: Individual results for the short-term drift 1 Test gas application:

at beginning		
zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
15:20:00	0.6	0.0
15:21:00	0.6	0.0
15:22:00	0.6	0.0
15:23:00	0.0	0.0
15:24:00	0.6	0.0
15:25:00	0.0	0.0
15:26:00	0.0	0.0
15:27:00	0.0	-0.6
15:28:00	0.0	0.0
15:29:00	0.0	0.0
15:30:00	0.0	-0.6
15:31:00	0.0	-0.6
15:32:00	0.0	-0.6
15:33:00	0.0	-0.6
15:34:00	0.0	-0.6
15:35:00	0.0	-0.6
15:36:00	0.0	-0.6
15:37:00	0.0	-0.6
15:38:00	0.0	-0.6
15:39:00	0.0	-0.6
average	**0.1**	**-0.3**

at beginning		
span level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
15:45:00	711.9	712.5
15:46:00	711.9	712.5
15:47:00	711.9	712.5
15:48:00	711.9	711.9
15:49:00	711.9	711.9
15:50:00	712.5	712.5
15:51:00	711.9	712.5
15:52:00	712.5	712.5
15:53:00	712.5	712.5
15:54:00	713.1	713.1
15:55:00	712.5	711.9
15:56:00	711.9	712.5
15:57:00	711.9	712.5
15:58:00	712.5	713.1
15:59:00	713.1	711.9
16:00:00	713.7	713.1
16:01:00	713.1	713.7
16:02:00	712.5	712.5
16:03:00	713.1	713.1
16:04:00	713.1	713.1
average	**712.5**	**712.6**

Table 11: Individual results for the short-term drift 2 Test gas application:

after 12h		
zero level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
03:20:00	0.0	-0.6
03:21:00	0.0	-0.6
03:22:00	0.0	-0.6
03:23:00	0.0	-0.6
03:24:00	0.0	-0.6
03:25:00	0.0	-0.6
03:26:00	0.0	-0.6
03:27:00	0.0	-0.6
03:28:00	0.0	-0.6
03:29:00	0.0	-0.6
03:30:00	0.0	-0.6
03:31:00	0.0	-0.6
03:32:00	0.0	-0.6
03:33:00	0.0	-0.6
03:34:00	0.0	-0.6
03:35:00	0.0	-0.6
03:36:00	0.0	-0.6
03:37:00	0.0	-0.6
03:38:00	0.0	-0.6
03:39:00	0.0	-0.6
average	**0.0**	**-0.6**

after 12h		
span level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
03:45:00	711.9	713.1
03:46:00	711.3	713.1
03:47:00	711.3	712.5
03:48:00	711.9	712.5
03:49:00	711.3	711.9
03:50:00	711.9	712.5
03:51:00	711.9	712.5
03:52:00	711.3	713.1
03:53:00	711.3	713.1
03:54:00	711.3	713.7
03:55:00	711.9	713.1
03:56:00	712.5	713.1
03:57:00	712.5	714.3
03:58:00	713.1	714.3
03:59:00	713.7	713.7
04:00:00	713.1	714.3
04:01:00	713.7	714.3
04:02:00	713.1	714.9
04:03:00	713.7	714.3
04:04:00	713.7	714.9
average	**712.3**	**713.4**

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 (sr) at zero concentration and at concentration c_t shall be calculated according to:

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

Where:

s_r the repeatability standard deviation;

x_i the ith 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.of (500 ± 50) nmol/mol.

The detection limit, lower detection limit of the measuring system is calculated from the repeatability standard deviation and the slope of the calibration function determined in accordance with Chapter 8.4.6 according to the following equation:

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

Where:

$l_{\det}$ is the detection limit, lower detection limit of the measuring system, in nmol/mol;

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

B is the slope of the calibration function according to Annex A based on the data from 8.4.6.

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.

7.4 Evaluation

Table 12 presents the results for the repeatability standard deviation.

Table 12: Repeatability standard deviation at zero and reference point

	requirement	device 1		device 2	
repeatability standard deviation $s_{r,z}$ at zero [nmol/mol]	≤ 1,0	0.13	✓	0.25	✓
repeatability standard deviation $s_{r,ct}$ at c_t [nmol/mol]	≤ 3,0	0.35	✓	0.39	✓
detection limit [nmol/mol]		0.43		0.81	

7.5 Assessment

For instrument 1 the value for the repeatability standard deviation at zero point was 0.13 nmol/mol, for instrument 2 it was 0.25 nmol/mol. Repeatability standard deviation at reference point was 0.35 nmol/mol for instrument 1 and 0.39 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		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
11:05:00	0.6	0.0
11:06:00	0.0	0.0
11:07:00	0.0	0.0
11:08:00	0.0	0.0
11:09:00	0.0	-0.6
11:10:00	0.0	-0.6
11:11:00	0.0	-0.6
11:12:00	0.0	-0.6
11:13:00	0.0	-0.6
11:14:00	0.0	-0.6
11:15:00	0.0	-0.6
11:16:00	0.0	-0.6
11:17:00	0.0	-0.6
11:18:00	0.0	-0.6
11:19:00	0.0	-0.6
11:20:00	0.0	-0.6
11:21:00	0.0	-0.6
11:22:00	0.0	-0.6
11:23:00	0.0	-0.6
11:24:00	0.0	-0.6
average	0.0	-0.5

c_t level		
	device 1	device 2
time	[nmol/mol]	[nmol/mol]
11:30:00	496.6	496.6
11:31:00	496.6	496.0
11:32:00	496.6	496.0
11:33:00	497.2	496.6
11:34:00	497.2	497.2
11:35:00	497.2	497.2
11:36:00	497.2	496.6
11:37:00	497.8	497.2
11:38:00	497.2	496.6
11:39:00	497.2	496.6
11:40:00	497.2	496.6
11:41:00	497.2	497.2
11:42:00	497.2	496.6
11:43:00	497.2	496.6
11:44:00	497.8	497.2
11:45:00	497.2	496.6
11:46:00	496.6	497.2
11:47:00	496.6	497.2
11:48:00	497.2	496.6
11:49:00	497.2	497.2
average	497.1	496.8

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 90% of the maximum of the certification range. At each concentration (including zero) at least five individual 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 are 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 $\left(= \sum (X_i / n)\right)$
- X_i is the individual x-value.

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

$A = a – B * X_z$

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

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

Where:

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

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

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

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

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

7.3 Testing

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

7.4 Evaluation

The following linear regressions were established:

Figure 8 and Figure 9 summarise the results of the group averages.

Table 14: Deviation from the analytical function for NO

	requirements	device 1		device 2	
largest value of the relative residuals r_{max} [%]	≤ 4,0	1.13	✓	0.82	✓
residual at zero r_z [nmol/mol]	≤ 5,0	0.12	✓	-0.36	✓

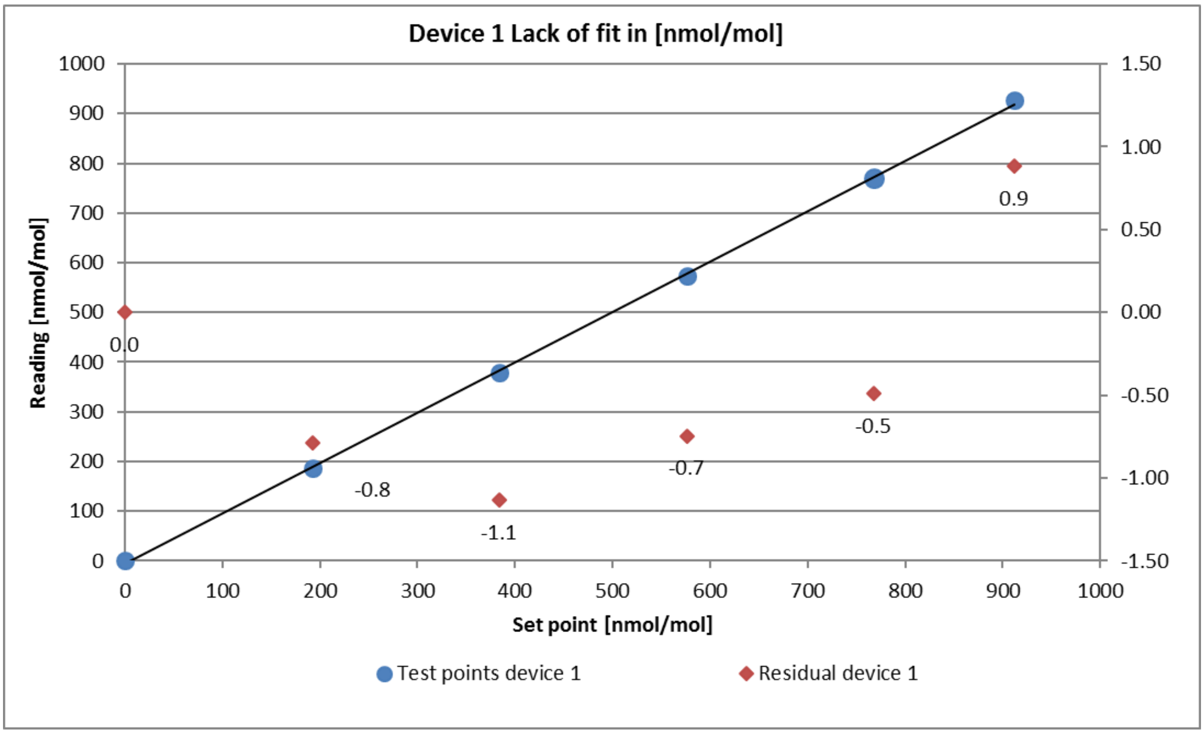


Figure 8: Analytical function obtained from the group averages for system 1

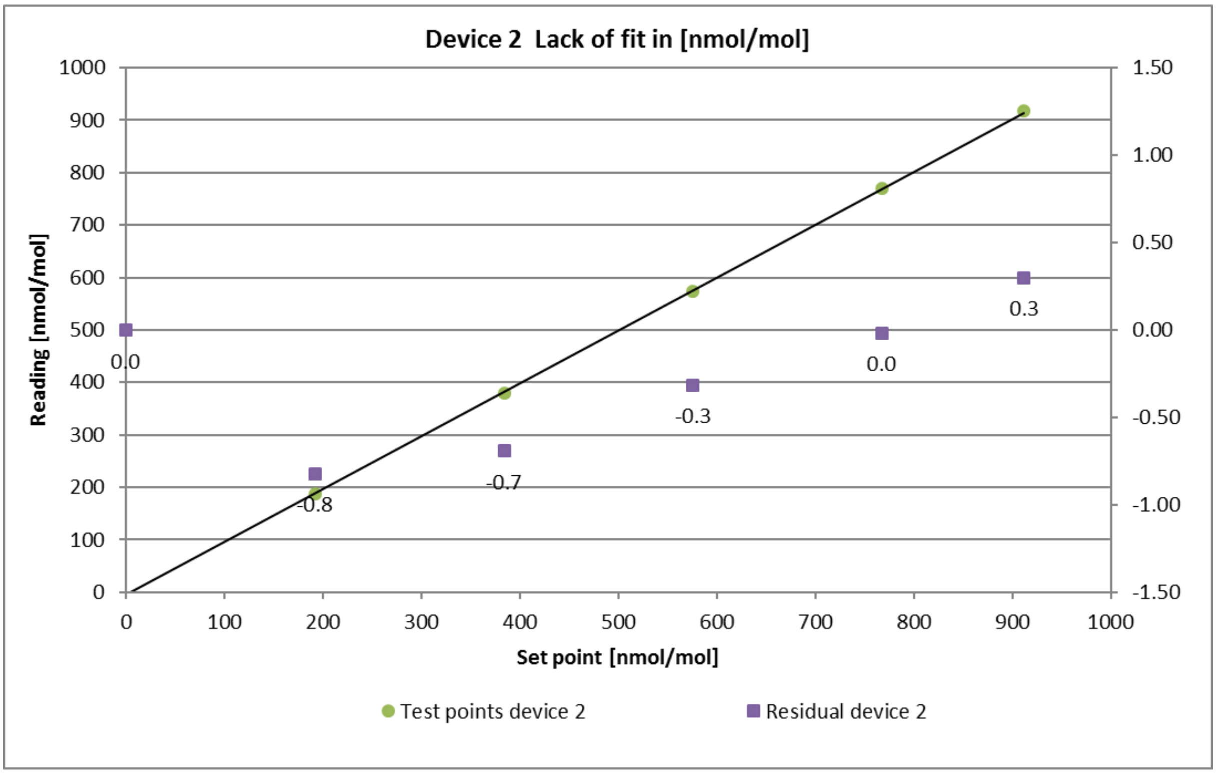


Figure 9: Analytical function obtained from the group averages for system 2

7.5 Assessment

The deviation from the linear regression line for instrument 1 is 0.12 nmol/mol at zero point and no more than 1.13% of the target value for concentrations above zero. The deviation from the linear regression line for instrument 2 is -0.36 nmol/mol at zero point and no more than 0.82% 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.

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
10:15:00	80	769.60	768.00	768.40	768.00
10:16:00	80	768.40	768.00	768.40	768.00
10:17:00	80	768.40	768.00	769.60	768.00
10:18:00	80	769.00	768.00	769.60	768.00
10:19:00	80	769.60	768.00	769.00	768.00
average		769.00		769.00	
$r_{c,rel}$		-0.49		-0.02	
10:23:00	40	378.79	384.00	379.99	384.00
10:24:00	40	379.39	384.00	379.99	384.00
10:25:00	40	379.39	384.00	380.59	384.00
10:26:00	40	378.79	384.00	379.99	384.00
10:27:00	40	379.39	384.00	379.39	384.00
average		379.15		379.99	
$r_{c,rel}$		-1.13		-0.69	
10:31:00	0	0.60	0.00	0.00	0.00
10:32:00	0	0.00	0.00	0.00	0.00
10:33:00	0	0.00	0.00	-0.60	0.00
10:34:00	0	0.00	0.00	-0.60	0.00
10:35:00	0	0.00	0.00	-0.60	0.00
average		0.12		-0.36	
r_z					
10:39:00	60	574.19	576.00	574.19	576.00
10:40:00	60	573.59	576.00	573.59	576.00
10:41:00	60	573.59	576.00	574.19	576.00
10:42:00	60	573.59	576.00	574.19	576.00
10:43:00	60	574.19	576.00	574.19	576.00
average		573.83		574.07	
$r_{c,rel}$		-0.75		-0.32	
10:47:00	20	186.99	192.00	187.59	192.00
10:48:00	20	186.99	192.00	187.59	192.00
10:49:00	20	187.59	192.00	188.19	192.00
10:50:00	20	187.59	192.00	188.19	192.00
10:51:00	20	187.59	192.00	187.59	192.00
average		187.35		187.83	
$r_{c,rel}$		-0.79		-0.82	
10:55:00	95	925.93	912.00	916.31	912.00
10:56:00	95	927.13	912.00	916.91	912.00
10:57:00	95	927.13	912.00	917.51	912.00
10:58:00	95	927.13	912.00	916.91	912.00
10:59:00	95	926.53	912.00	916.31	912.00
average		926.77		916.79	
$r_{c,rel}$		0.88		0.30	

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.

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

Where:

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

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.

7.3 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.

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

7.4 Evaluation

The following sensitivity coefficients to sample gas pressure were determined:

Table 16 Sensitivity coefficient of sample gas pressure

	requirement	device 1		device 2	
sensitivity coeff. sample gas pressure b_{gp} [nmol/mol/kPa]	≤ 8,0	0.30	✓	0.29	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas pressure is 0.30 nmol/mol/kPa.
For instrument 2, the sensitivity coefficient to sample gas pressure is 0.29 nmol/mol/kPa.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 17: Individual results of the sensitivity to changes in sample gas pressure

time	pressure [kPa]	concentration	device 1 [nmol/mol]	device 2 [nmol/mol]
15:48:00	80	730.00	744.35	740.14
15:49:00	80	730.00	744.95	741.94
15:50:00	80	730.00	745.55	742.54
average C_{P1}			744.95	741.54
15:58:00	110	730.00	735.33	732.92
15:59:00	110	730.00	735.93	732.92
16:00:00	110	730.00	736.53	732.92
average C_{P2}			735.93	732.92

7.1 8.4.8 Sensitivity coefficient to sample gas temperature

The sensitivity coefficient to sample gas temperature shall be ≤ 3.0 µmol/mol/K.

7.2 Test procedures

Measurements shall be performed at sample gas temperatures of $T_{G,1}$ = 0 °C and $T_{G,2}$ = 30 °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 sample gas temperature $T_{G,1}$;

$T_{G,2}$ is the sample gas temperature $T_{G,2}$;

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

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.

7.3 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 40 m tube-bundle which was 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 °C. For the purpose of testing a gas temperature of 30 °C, gas was led through a heated line instead of the tube bundle in the climatic chamber.

7.4 Evaluation

Table 18 Sensitivity coefficient to sample gas temperature

	requirement	device 1		device 2	
sensitivity coeff. sample gas temperature b_{gt} [nmol/mol/K]	≤ 3,0	0.13	✓	0.05	✓

7.5 Assessment

For instrument 1, the sensitivity coefficient to sample gas temperature is 0.13 nmol/mol/K.
For instrument 2, the sensitivity coefficient to sample gas temperature is 0.05 nmol/mol/K.
Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 19: Individual results for the determination of the sensitivity to sample gas temperature

			device 1	device 2
time	temp [ºC]	concentration	[nmol/mol]	[nmol/mol]
07:20:00	0	720.00	726.91	724.51
07:21:00	0	720.00	726.31	724.51
07:22:00	0	720.00	726.91	724.51
average $C_{GT,1}$			726.71	724.51
09:14:00	30	720.00	723.91	726.91
09:15:00	30	720.00	722.70	725.71
09:16:00	30	720.00	722.10	725.71
average $C_{GT,2}$			722.90	726.11

7.1 8.4.9 Sensitivity coefficient to surrounding temperature

The sensitivity coefficient to surrounding temperature temperature shall be ≤ 3.0 µmol/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.

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.

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_I, T_{min}, T_I and T_I, T_{max}, T_I

At the first temperature (T_I), 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_I, at T_{min} and again at T_I. This measurement procedure shall be repeated at the temperature sequence of T_I, T_{max} and at T_I.

In order to exclude any possible drift due to factors other than temperature, the measurements at T_I 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 ºC for zero level [nmol/mol/K]	≤ 3,0	0.040	✓	0.020	✓
sensitivity coefficient at 30 ºC for zero level [nmol/mol/K]	≤ 3,0	0.090	✓	0.050	✓
sensitivity coefficient at 0 ºC for span level [nmol/mol/K]	≤ 3,0	0.601	✓	0.165	✓
sensitivity coefficient at 30 ºC for span level [nmol/mol/K]	≤ 3,0	0.581	✓	0.271	✓

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 0.601 nmol/mol/K for instrument 1 and 0.271 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 coefficient to ambient temperature

	zero level				span level			
			device 1	device 2			device 1	device 2
date	time	temp [ºC]	[nmol/mol]	[nmol/mol]	time	temp [ºC]	[nmol/mol]	[nmol/mol]
19.06.2018	07:31:00	20	0.6	0.0	07:48:00	20	723.3	720.9
19.06.2018	07:32:00	20	0.6	0.0	07:49:00	20	723.9	720.3
19.06.2018	07:33:00	20	0.6	0.0	07:50:00	20	723.9	720.9
average ($X_{1(TS1)}$)			0.6	0.0			723.7	720.7
19.06.2018	14:14:00	0	1.8	1.2	14:29:00	0	735.3	723.3
19.06.2018	14:15:00	0	1.8	0.6	14:30:00	0	734.7	724.5
19.06.2018	14:16:00	0	1.8	0.6	14:31:00	0	735.9	724.5
average($X_{Ts,1}$)		0	1.8	0.8			735.3	724.1
20.06.2018	14:00:00	20	1.8	1.2	14:15:00	20	722.7	720.9
20.06.2018	14:01:00	20	1.2	0.6	14:16:00	20	722.7	721.5
20.06.2018	14:02:00	20	1.2	0.6	14:17:00	20	723.3	720.3
average ($X_{2(TS1)}$) = ($X_{1(TS2)}$)			1.4	0.8			722.9	720.9
21.06.2018	07:19:00	30	0.6	0.6	07:34:00	30	716.7	723.3
21.06.2018	07:20:00	30	0.6	0.6	07:35:00	30	716.1	723.3
21.06.2018	07:21:00	30	0.6	0.6	07:36:00	30	716.7	723.9
average($X_{Ts,2}$)			0.6	0.6			716.5	723.5
21.06.2018	13:49:00	20	1.8	1.2	14:04:00	20	721.5	720.9
21.06.2018	13:50:00	20	1.8	1.2	14:05:00	20	721.5	720.3
21.06.2018	13:51:00	20	1.2	1.8	14:06:00	20	722.1	720.9
average ($X_{2(TS2)}$)			1.6	1.4			721.7	720.7

7.1 8.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient to electrical voltage shall not exceed 0.3 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

	requirement	device 1		device 2	
sensitivity coeff. of voltage b_v at zero level [nmol/mol/V]	≤ 0,3	0.00	✓	0.00	✓
sensitivity coeff. of voltage b_v at span level [nmol/mol/V]	≤ 0,3	0.04	✓	0.00	✓

7.5 Assessment

At no test item did the sensitivity coefficient to electrical voltage b_v exceed the value of 0.3 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 0.04 nmol/mol/V and for instrument 2 it is 0.00 nmol/mol/V.

Criterion satisfied? yes

7.6 Detailed presentation of test results

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

time	voltage [V]	concentration	device 1 [nmol/mol]	device 2 [nmol/mol]
12:16:00	207	0	0.00	-0.60
12:17:00	207	0	0.00	-0.60
12:18:00	207	0	0.00	-0.60
average C_{V1} at zero			0.00	-0.60
12:26:00	253	0	0.00	-0.60
12:27:00	253	0	0.00	-0.60
12:28:00	253	0	0.00	-0.60
average C_{V2} at zero			0.00	-0.60
12:35:00	207	720.00	722.10	718.49
12:36:00	207	720.00	722.10	717.89
12:37:00	207	720.00	722.10	719.10
average C_{V1} at Span			722.10	718.49
12:45:00	253	720.00	723.91	717.89
12:46:00	253	720.00	723.91	719.10
12:47:00	253	720.00	723.91	718.49
average C_{V2} at Span			723.91	718.49

7.1 8.4.11 Interferents

Interferents at zero and at concentration c_t for NO (500 ± 50 nmol/mol). Deviations for interferents H_2O, CO_2 and NH_3 shall not exceed 5.0 nmol/mol.

7.2 Test procedures

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 ≤ 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 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 NOx concentration shall be used instead of the NO concentration when testing the interferent NH_3.

Table 24: Interferents in accordance with EN 14211

Interferent	Value
H_2O	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. When determining the influence of moisture, the dilution effect which occurs inside the test gas generation system was also taken into account.

Table 25: Influence of the tested interferents (c_t = 500±50 nmol/mol)

	requirements	**device 1**		**device 2**	
influence quantity interferent H_2O at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.20	✓	-0.20	✓
influence quantity interferent H_2O at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	-0.20	✓	-0.60	✓
influence quantity interferent CO_2 at zero [nmol/mol/V]	≤ 5.0 nmol/mol	0.60	✓	0.00	✓
influence quantity interferent CO_2 at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	-0.20	✓	0.20	✓
influence quantity interferent NH_3 at zero [nmol/mol/V]	≤ 5.0 nmol/mol	1.60	✓	1.80	✓
influence quantity interferent NH3 at c_t [nmol/mol/V]	≤ 5.0 nmol/mol	2.00	✓	2.40	✓

7.5 Assessment

At zero point the result for the interference were 0.20 nmol/mol (AMS 1) and -0.20 nmol/mol (AMS 2) for H_2O, 0.60 nmol/mol (AMS 1) and 0.00 nmol/mol (AMS 2) for CO_2 and finally 1.60 nmol/mol (AMS 1) and 1.80 nmol/mol (AMS 2) for NH_3.

The following results were obtained for the cross-sensitivity at the limit value c_t: NO: -0.20 nmol/mol for instrument 1 and -0.60 nmol/mol for instrument 2; H_2O: -0.20 nmol/mol for instrument 1 and 0.20 nmol/mol for instrument 2; CO_2 and 2.00 nmol/mol for instrument 1 and 2.40 nmol/mol at NH_3.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 26 presents the individual test results.

Table 26: Individual results for testing interferents

	without interferents			with interferents		
	time	device 1	device 2	time	device 1	device 2
zero gas + H_2O (19 mmol/mol)	09:41:00	0.60	0.00	09:49:00	0.60	0.00
	10:42:00	0.00	0.00	10:50:00	0.60	0.00
	10:43:00	0.60	0.60	10:51:00	0.60	0.00
	average x_z	0.40	0.20	average x_z	0.60	0.00
test gas c_t + H_2O (19 mmol/mol)	09:59:00	500.84	500.84	10:09:00	500.24	500.84
	10:00:00	500.24	501.44	10:10:00	500.24	500.24
	10:01:00	500.24	502.04	10:11:00	500.24	501.44
	average x_{ct}	500.44	501.44	average x_{ct}	500.24	500.84
zero gas + CO_2 (500 µmol/mol)	11:00:00	0.00	0.00	11:10:00	0.60	0.00
	11:01:00	0.00	0.00	10:11:00	0.60	0.00
	11:02:00	0.00	0.00	10:12:00	0.60	0.00
	average x_z	0.00	0.00	average x_z	0.60	0.00
test gas c_t + CO_2 (500 µmol/mol)	11:33:00	504.45	506.25	11:43:00	503.85	506.25
	11:34:00	504.45	505.65	11:44:00	504.45	506.25
	11:35:00	504.45	505.65	11:45:00	504.45	505.65
	average x_{ct}	504.45	505.85	average x_{ct}	504.25	506.05
zero gas + NH_3 (200 nmol/mol)	10:20:00	0.60	0.00	10:30:00	3.01	2.41
	10:21:00	0.60	0.00	10:31:00	2.41	2.41
	10:22:00	0.60	0.00	10:32:00	1.20	0.60
	average x_z	0.60	0.00	average x_z	2.20	1.80
test gas c_t + NH_3 (200 nmol/mol)	10:40:00	506.25	505.05	10:50:00	508.06	507.46
	10:41:00	506.25	505.65	10:51:00	508.06	508.06
	10:42:00	506.25	505.05	10:52:00	508.66	507.46
	average x_{ct}	508.26	505.25	average x_{ct}	508.26	507.66

NO_x reading with interference from NH_3

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 NO_2 at a concentration $c_{t,NO2}$ 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:

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

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} 0x1is the average of the at least four independent measurements during the variable concentration period;

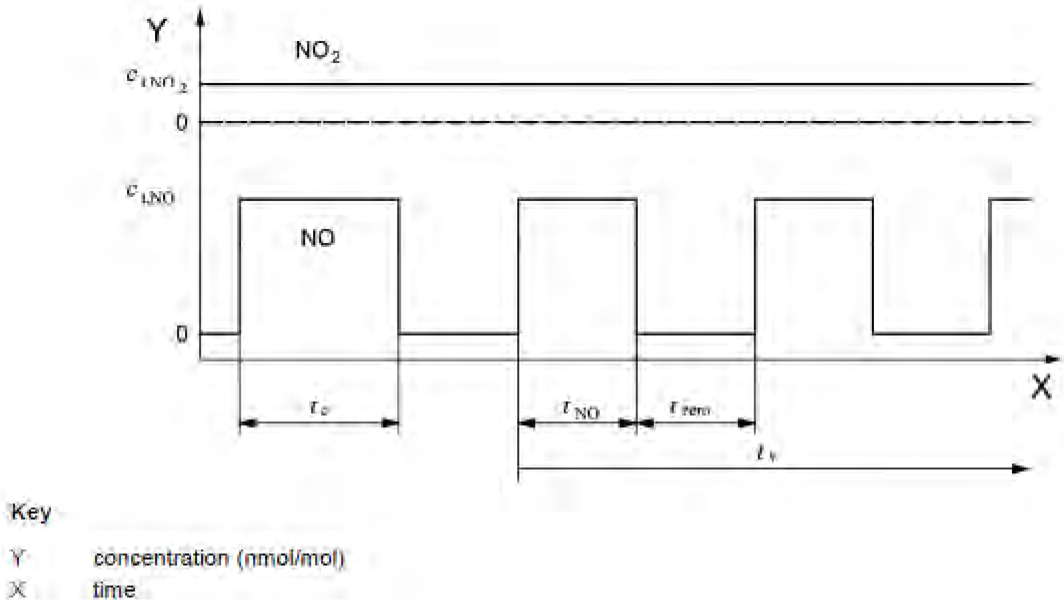


Figure 10: Test of the averaging effect (t_{NO} = t_{zero} = 45 s.)

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 NO_2 concentration $c_{t,NO2}$ 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

The following averages were determined during the test:

Table 27: Results of the averaging test

	requirement	device 1		device 2	
averaging effect E_{av} [%]	≤ 7%	-3.4	✓	-0.4	✓

This results in the following averaging effects:

System 1 (12): -3.4 %

System 2 (14): -0.4 %

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 28 presents the individual results of the averaging test:

Table 28: Individual results of the averaging test

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	12:52:00 till 13:11:00	595.4	596.1
average variable concentration $C_{av,c}$	13:12:00 till 13:31:00	308.4	296.3

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	13:42:00 till 14:01:00	596.8	597.9
average variable concentration $C_{av,c}$	14:02:00 till 14:21:00	310.9	299.2

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
average constant concentration $C_{av,c}$	14:33:00 till 14:52:00	597.8	598.5
average variable concentration $C_{av,c}$	14:53:00 till 15:12:00	306.4	304.3

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:

$$\Delta x_{SC} = \frac{x_{sam} - x_{cal}}{c_t} \times 100$$

Where:

Δx_{SC}	is the difference sample/calibration port;
x_{sam}	is the average of the measured concentration using the sample port;
x_{cal}	is the average of the measured concentration using the calibration port;
c_t	is the concentration of the test gas;
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:

Table 29: Results of determining the difference between sample/calibration inlet

	requirement	device 1		device 2	
difference sample/calibration port Δx_{cs} [%]	≤ 1%	-0.33	✓	-0.19	✓

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 30 presents the individual values.

Table 30: Individual results for testing the difference between sample and calibration port

		device 1	device 2
	time	[nmol/mol]	[nmol/mol]
calibration port	16:12:00	723.3	720.9
	16:13:00	723.9	721.5
	16:14:00	723.9	721.5
sample port	16:24:00	725.7	723.3
	16:25:00	726.3	722.1
	16:26:00	726.3	722.7

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 NO_2. This can be achieved by means of gas-phase titration of NO to NO_2 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 NO_2.

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 O_3 to produce NO_2. 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 O_3 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 NOx channel at the initial NOx 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 O_3;
$(NO)_i$	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 O_3;

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 NO_2 concentrations in the range of 50% to 95% of the certification range for NO_2 were adjusted by means of gas-phase titration.

7.4 Evaluation

During the test, the following converter efficiencies were determined for the two 42iQ measuring systems. The lowest value of the two NO_2 concentration is reported below.

	requirement	device 1		device 2	
converter efficiency E_c [%]	≥ 98%	99.5	✓	98.5	✓

7.5 Assessment

At a converter efficiency of 98.5%, the performance criterion specified by EN 14211 is fully satisfied.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 31 presents the individual values.

Table 31: Individual results for the converter efficiency

				device 1		device 2	
	time	O_3 [nmol/mol]	NO_2 [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]	NO [nmol/mol]	NO_x [nmol/mol]
	13:32:00	s t a r t					
O_3=0, NO=50%	13:44:00	0.0	-0.2	480.4	482.2	481.6	481.6
	13:45:00	0.0	0.2	479.8	482.2	481.6	481.6
	13:46:00	0.0	-0.2	480.4	482.2	482.2	482.2
	13:47:00	0.0	0.0	479.8	482.8	482.2	482.2
average		0.0	0.0	480.1	482.4	481.9	481.9
NO_2= 50%	14:07:00	135.0	131.2	351.7	481.6	351.1	481.0
	14:08:00	135.0	131.7	351.7	481.6	352.3	482.2
130.75	14:09:00	135.0	131.9	351.7	481.6	352.3	482.2
	14:10:00	135.0	132.1	351.1	482.2	352.9	482.2
average		135.0	131.7	351.6	481.8	352.2	481.9
O_3=0, NO=50%	14:44:00	0.0	2.3	483.4	487.0	485.2	485.8
	14:45:00	0.0	2.3	484.0	486.4	485.2	485.2
	14:46:00	0.0	2.1	484.6	487.0	486.4	485.8
	14:47:00	0.0	2.9	484.0	487.0	485.2	485.2
average		0.0	2.4	484.0	486.9	485.5	485.5
NO_2= 95%	15:08:00	250.0	246.6	238.1	485.8	237.5	481.6
	15:09:00	250.0	248.0	237.5	485.8	236.9	481.6
248.43	15:10:00	250.0	247.8	238.1	486.4	236.9	482.2
	15:11:00	250.0	247.2	237.5	486.4	237.5	482.2
average		250.0	247.4	237.8	486.1	237.2	481.9
O_3=0, NO=50%	15:27:00	0.0	0.0	481.0	480.2	479.6	481.2

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

The gas volume of the 42iQ measuring system is approximately 35.0 ml from the sample inlet to the measuring cell. The typical sample gas flow is at 1.0 l/min. This results in a residence time in the analyser of 2.2 s.

7.4 Evaluation

Not applicable.

7.5 Assessment

Residence time in the analyser was 2.2 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_t;

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

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

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

7.3 Testing

For the purpose of this test, test gas was applied every other week. Table 32 and Table 33 report the measured values for bi-weekly test gas applications. 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 32: Results for the long-term drift at zero point

		requierment	Device 1		Device 2	
average start $Cz_{,1}$ at zero [nmol/mol]	25.06.2018	≤ 5,0 nmol/mol	--	✓	--	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	09.07.2018	≤ 5,0 nmol/mol	0.00	✓	0.00	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	23.07.2018	≤ 5,0 nmol/mol	1.20	✓	1.20	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	06.08.2018	≤ 5,0 nmol/mol	0.00	✓	0.00	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	20.08.2018	≤ 5,0 nmol/mol	0.00	✓	0.60	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	03.09.2018	≤ 5,0 nmol/mol	0.00	✓	0.48	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	17.09.2018	≤ 5,0 nmol/mol	0.00	✓	0.48	✓
long term drift $D_{L,Z}$ at zero [nmol/mol]	01.10.2018	≤ 5,0 nmol/mol	0.00	✓	0.00	✓

Table 33: Results for the long-term drift at reference point

		requierment	Device 2 1		Device 2	
average start $Cs_{,1}$ at span [nmol/mol]	25.06.2018	≤ 5 %	--	✓	--	✓
long term drift $D_{L,S}$ at span [nmol/mol]	09.07.2018	≤ 5 %	0.24	✓	0.20	✓
long term drift $D_{L,S}$ at span [nmol/mol]	23.07.2018	≤ 5 %	0.14	✓	-0.15	✓
long term drift $D_{L,S}$ at span [nmol/mol]	06.08.2018	≤ 5 %	0.19	✓	0.02	✓
long term drift $D_{L,S}$ at span [nmol/mol]	20.08.2018	≤ 5 %	-0.01	✓	-0.27	✓
long term drift $D_{L,S}$ at span [nmol/mol]	03.09.2018	≤ 5 %	0.19	✓	0.05	✓
long term drift $D_{L,S}$ at span [nmol/mol]	17.09.2018	≤ 5 %	-0.08	✓	-0.17	✓
long term drift $D_{L,S}$ at span [nmol/mol]	01.10.2018	≤ 5 %	0.22	✓	0.64	✓

7.5 Assessment

Maximum long-term drift at zero point $D_{l,z}$ was at 1.20 nmol/mol for instrument 1 and 1.20 nmol/mol for instrument 2. Maximum long-term drift at reference point $D_{l,s}$ was at 0.24% for instrument 1 and 0.64% for instrument 2.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 34 presents the individual values obtained for the determination of the long-term drift.

Table 34: Individual results for differences

Zero Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
25.06.2018	09:52:00	0.00	0.00
	09:53:00	0.00	0.00
	09:54:00	0.00	0.00
	Mittel	0.00	0.00
	09:56:00	0.00	0.00
	09:57:00	0.00	0.00
	09:58:00	0.00	0.00
	Mittel	0.00	0.00
	10:00:00	0.00	0.00
	10:01:00	0.00	0.00
	10:02:00	0.00	0.00
	Mittel	0.00	0.00
	10:04:00	0.00	0.00
	10:05:00	0.00	0.00
	10:06:00	0.00	0.00
	Mittel	0.00	0.00
	10:08:00	0.00	0.00
	10:09:00	0.00	0.00
	10:10:00	0.00	0.00
		0.00	0.00
Average field start $c_{z,0}$		**0.00**	**0.00**
09.07.2018	13:45:00	0.00	0.00
	13:46:00	0.00	0.00
	13:47:00	0.00	0.00
	13:48:00	0.00	0.00
	13:49:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
23.07.2018	10:00:00	1.20	1.20
	10:01:00	1.20	1.20
	10:02:00	1.20	1.20
	10:03:00	1.20	1.20
	10:04:00	1.20	1.20
	aver. $c_{z,1}$	**1.20**	**1.20**
06.08.2018	10:06:00	0.00	0.00
	10:07:00	0.00	0.00
	10:08:00	0.00	0.00
	10:09:00	0.00	0.00
	10:10:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**
20.08.2018	13:58:00	0.00	0.60
	13:59:00	0.00	0.60
	14:00:00	0.00	0.60
	14:01:00	0.00	0.60
	14:02:00	0.00	0.60
	aver. $c_{z,1}$	**0.00**	**0.60**
03.09.2018	11:05:00	0.00	0.60
	11:06:00	0.00	0.60
	11:07:00	0.00	0.60
	11:08:00	0.00	0.00
	11:09:00	0.00	0.60
	aver. $c_{z,1}$	**0.00**	**0.48**
17.09.2018	10:15:00	0.00	0.60
	10:16:00	0.00	0.60
	10:17:00	0.00	0.00
	10:18:00	0.00	0.60
	10:19:00	0.00	0.60
	aver. $c_{z,1}$	**0.00**	**0.48**
01.10.2018	13:05:00	0.00	0.00
	13:06:00	0.00	0.00
	13:07:00	0.00	0.00
	13:08:00	0.00	0.00
	13:09:00	0.00	0.00
	aver. $c_{z,1}$	**0.00**	**0.00**

C_t-Concentration			
		Device 1	Device 2
Date	Time	[nmol/mol]	[nmol/mol]
25.06.2018	10:20:00	720.90	720.30
	10:21:00	721.50	720.30
	10:22:00	720.90	721.50
	Mittel	721.10	720.70
	10:24:00	722.70	722.10
	10:25:00	720.30	722.10
	10:26:00	720.30	722.10
	Mittel	721.10	722.10
	10:28:00	721.50	723.91
	10:29:00	722.10	723.30
	10:30:00	723.30	725.11
	Mittel	722.30	724.11
	10:32:00	723.30	724.51
	10:33:00	723.30	723.30
	10:34:00	720.30	721.50
	Mittel	722.30	723.10
	10:36:00	721.50	722.70
	10:37:00	721.50	723.30
	10:38:00	722.10	722.70
		721.70	722.90
Average field start $c_{s,0}$		**721.70**	**722.58**
09.07.2018	14:00:00	722.70	723.30
	14:01:00	722.10	723.30
	14:02:00	723.30	723.91
	14:03:00	724.51	724.51
	14:04:00	724.51	725.11
	aver. $c_{s,1}$	**723.42**	**724.03**
23.07.2018	10:15:00	722.70	722.10
	10:16:00	722.70	722.10
	10:17:00	723.91	723.30
	10:18:00	725.11	722.70
	10:19:00	725.11	723.30
	aver. $c_{s,1}$	**723.91**	**722.70**
06.08.2018	10:21:00	724.51	723.91
	10:22:00	725.11	723.91
	10:23:00	722.10	722.70
	10:24:00	720.90	721.50
	10:25:00	722.70	721.50
	aver. $c_{s,1}$	**723.06**	**722.70**
20.08.2018	14:13:00	722.10	722.70
	14:14:00	720.90	720.90
	14:15:00	720.90	720.30
	14:16:00	721.50	720.90
	14:17:00	722.70	721.50
	aver. $c_{s,1}$	**721.62**	**721.26**
03.09.2018	11:20:00	722.10	722.70
	11:21:00	722.10	723.30
	11:22:00	723.30	722.70
	11:23:00	723.91	723.91
	11:24:00	723.91	724.51
	aver. $c_{s,1}$	**723.06**	**723.42**
17.09.2018	10:30:00	721.50	722.70
	10:31:00	720.90	721.50
	10:32:00	720.90	721.50
	10:33:00	720.90	721.50
	10:34:00	721.50	722.10
	aver. $c_{s,1}$	**721.14**	**721.86**
01.10.2018	13:20:00	722.70	726.91
	13:21:00	723.30	726.91
	13:22:00	723.91	727.51
	13:23:00	723.30	727.51
	13:24:00	723.30	727.51
	aver. $c_{s,1}$	**723.30**	**727.27**

7.1 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.

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.

7.4 Evaluation

Table 35: Determination of the reproducibility standard deviation on the basis of complete field test data

reproducibility standard deviation in field		
no. of measurments (1h- average)	[n]	2359
average of both analyzers (3 month)	[nmol/mol]	14.13
standard deviation from paired measurements	[nmol/mol]	0.345
reproducibility standard deviation in field $S_{r,f}$	**[%]**	**2.44**
requirement	≤ 5,0 %	✓

The reproducibility standard deviation under field conditions is at 2.44% of the average.

7.5 Assessment

The reproducibility standard deviation for NO_2 under field conditions was 2.44% 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 11 provides an illustration of the reproducibility standard deviation under field conditions.

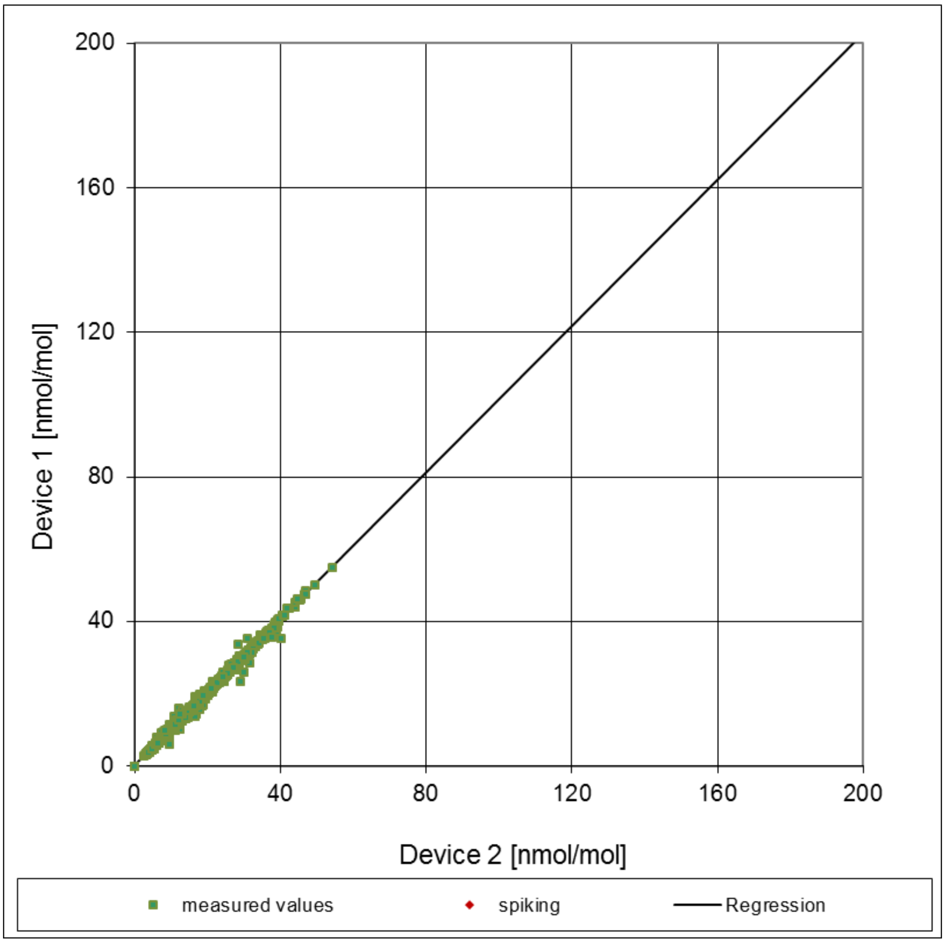


Figure 11: Diagram illustrating the reproducibility standard deviation under field conditions

7.1 8.5.6 Inspection interval

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

7.2 Equipment

Not required for this performance criterion

7.3 Testing

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

7.4 Evaluation

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

During the three months field test period, maintenance is generally limited to contamination and plausibility checks and potential status/error messages. Naturally, the frequency of filter replacement will depend on the ambient dust concentration at the site of installation. Chapter 5 of the manual and Chapter 8 of this report provide information about tasks to be performed in the maintenance interval.

7.5 Assessment

The necessary maintenance tasks determine the period of unattended operation. In essence, these include contamination checks, plausibility checks and checks of potential status/error warnings. The external particle filter needs replacing at the measurement site after having been subjected to dust loading. EN 14211 requires checking of zero and span points at least once every two weeks.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 8.5.7 Period of availability of the analyser

Availability of the analyser shall be at least 90%.

7.2 Test procedures

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

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

The availability of the analyser is calculated as:

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

Where:

A_a is the availability of the analyser (%);

t_u is the total time period with validated measuring data;

t_t is the time period of the field test minus the time for calibration, conditioning and maintenance, t_u and t_t shall be expressed in the same units.

The availability shall comply with the performance criterion indicated above.

7.3 Testing

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

Evaluation

Outage times which have occurred during the field test are listed in Table 36.

Table 36: Availability of the 42iQ measuring system

		System 1	System 2
Operation time	h	2359	2359
Outage time	h	0	0
Maintenance time	h	8	8
Actual operating time:	h	2351	2351
Actual operating time incl. maintenance times:	h	2359	2359
Availability	%	100	100

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

7.5 Assessment

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

7.6 Detailed presentation of test results

Table 37 summarises the results for items 1 and 3.

Table 38 and Table 40 contain the results regarding item 2.

Table 39 and Table 41 contain the results regarding item 4.

Table 37: 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: 0.13 nmol/mol S_r system 2: 0.25 nmol/mol	yes	80
8.4.5 Repeatability standard deviation at concentration level c_t	≤ 3.0 nmol/mol	S_r system 1: 0.35 nmol/mol S_r system 2: 0.39 nmol/mol	yes	80
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	$X_{l,z}$ system 1: ZP 0.12 nmol/mol X_l system 1: RP 1.13% $X_{l,z}$ system 2: ZP -0.36 nmol/mol X_l system 2: RP 0.82%	yes	83
8.4.7 Sensitivity coefficient of sample gas pressure	≤ 8.0 nmol/mol/kPa	b_{gp} system 1: 0.30 nmol/mol/kPa b_{gp} system 2: 0.29 nmol/mol/kPa	yes	88
8.4.8 Sensitivity coefficient of sample gas temperature	≤ 3.0 nmol/mol/K	b_{gt} system 1: 0.13 nmol/mol/K b_{gt} system 2: 0.05 nmol/mol/K	yes	90
8.4.9 Sensitivity coefficient of surrounding temperature	≤ 3.0 nmol/mol/K	b_{st} system 1: 0.601 nmol/mol/K b_{st} system 2: 0.271 nmol/mol/K	yes	92
8.4.10 Sensitivity coefficient of electrical voltage	≤ 0.3 nmol/mol/V	b_v system 1: RP 0.04 nmol/mol/V b_v system 2: RP 0.00 nmol/mol/V	yes	95
8.4.11 Interferent at zero and at concentration level c_t	H_2O ≤ 5.0 nmol/mol CO_2 ≤ 5.0 nmol/mol NH_3 ≤ 5.0 nmol/mol	H_2O system 1 ZP -0.20 nmol/mol / RP -0.20 nmol/mol system 2 ZP -0.20 nmol/mol / RP -0.60 nmol/mol CO_2 system 1 ZP 0.60 nmol/mol / RP -0.20 nmol/mol system 2 ZP 0.00 nmol/mol / RP 0.20 nmol/mol NH_3 system 1 ZP 1.60 nmol/mol / RP 2.00 nmol/mol system 2 ZP 1.80 nmol/mol / RP 2.40 nmol/mol	yes	97

Performance characteristic	**Performance criterion**	**Test result**	**Satis-fied**	**Page**
8.4.12 Averaging effect	≤ 7.0% of the measured value	E_{av} system 1: -3.4% E_{av} system 2: -0.4%	yes	100
8.4.13 Difference sample/calibration port	≤ 1.0%	Δ_{SC} system 1: -0.33% Δ_{SC} system 2: -0.19%	yes	103
8.4.3 Response time (rise)	≤ 180 s	t_r system 1: 57 s (NO) t_r system 2: 58 s (NO) t_r system 1: 57 s (NO_2) t_r system 2: 57 s (NO_2)	yes	71
8.4.3 Response time (fall)	≤ 180 s	t_f system 1: 57 s (NO) t_f system 2: 56 s (NO) t_f system 1: 57.5 s (NO_2) t_f system 2: 57.5 s (NO_2)	yes	71
8.4.3 Difference between the rise and fall response time	≤ 10 s	t_d system 1: 0 s (NO) t_d system 2: -2s (NO) t_d system 1: -0.5s (NO_2) t_d system 2: -0.5s (NO_2)	yes	71
8.4.14 Converter efficiency	≥ 98%	E_{conv} system 1: 99.5% E_{conv} system 2: 98.5%	yes	105
8.4.15 Residence time	≤ 3.0 s	System 1 2.2 s System 2 2.2 s	yes	107
8.5.7 Availability of the analyser	> 90%	A_a system 1: 100% A_a system 2: 100%	yes	115
8.5.5 Reproducibility standard deviation under field conditions	≤ 5.0% of the average over a period of 3 months	$S_{r,f}$ system 1: 2.44% $S_{r,f}$ system 2: 2.44%	yes	111
8.5.4 Long-term drift at zero point	≤ 5.0 nmol/mol	$C_{,z}$ system 1: 1.20 nmol/mol $C_{,z}$ system 2: 1.20 nmol/mol	yes	108
8.5.4 Long-term drift at span level	≤ 5.0% of the upper limit of the certification range	$C_{,s}$ system 1: max. 0.24% $C_{,s}$ system 2: max. 0.64%	yes	108
8.4.4 Short-term drift at zero	≤ 2.0 nmol/mol over 12 h	$D_{s,z}$ system 1: -0.12 nmol/mol $D_{s,z}$ system 2: -0.27 nmol/mol	yes	76
8.4.4 Short-term drift at span level	≤ 6.0 nmol/mol over 12 h	$D_{s,s}$ system 1: -0.03 nmol/mol $D_{s,s}$ system 2: 1.14 nmol/mol	yes	76

Table 38: Expanded uncertainty from the results obtained in the laboratory tests for analyser 1

Measuring device:	42iQ	Serial-No.:	1180540003	
Measured component:	NO_2	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	0.130	$u_{r,z}$	0.03	0.0011	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.350	$u_{r,lh}$	0.02	0.0003	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	1.130	$u_{l,lh}$	0.68	0.4657	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.300	u_{gp}	0.74	0.5468	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.601	u_{st}	1.51	2.2870	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.040	u_V	0.12	0.0138	
8a	Interferent H_2O with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.200	u_{H2O}	0.09	0.0075	
		≤	10 nmol/mol (Span)	-0.200				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.600	$u_{int,pos}$ or $u_{int,neg}$	1.22	1.4929	
		≤	5.0 nmol/mol (Span)	-0.200				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	1.600				
		≤	5.0 nmol/mol (Span)	2.000				
9	Averaging effect	≤	7.0% of measured value	-3.400	u_{av}	-2.05	4.2160	
18	Difference sample/calibration port	≤	1.0%	-0.330	$u_{\Delta sc}$	-0.35	0.1191	
21	Converter efficiency	≥	98	99.50	u_{EC}	0.52	0.2735	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
				Combined standard uncertainty	u_c		3.2434	nmol/mol
				Expanded uncertainty	U		6.4867	nmol/mol
				Relative expanded uncertainty	W		6.20	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 39: Expanded uncertainty from the results obtained in the laboratory and field tests for analyser 1

Measuring device:	42iQ	Serial-No.:	1180540003	
Measured component:	NO_2	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	0.130	$u_{r,z}$	0.03	0.0011	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.350	$u_{r,lh}$	not considered, as √2*ur,lh = 0,02 < ur,f	-	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	1.130	$u_{l,lh}$	0.68	0.4657	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.300	u_{gp}	0.74	0.5468	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.601	u_{st}	1.51	2.2870	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.040	u_V	0.12	0.0138	
8a	Interferent H_2O with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.200	u_{H2O}	0.09	0.0075	
		≤	10 nmol/mol (Span)	-0.200				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.600	$u_{int,pos}$ or $u_{int,neg}$	1.22	1.4929	
		≤	5.0 nmol/mol (Span)	-0.200				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	1.600				
		≤	5.0 nmol/mol (Span)	2.000				
9	Averaging effect	≤	7.0% of measured value	-3.400	u_{av}	-2.05	4.2160	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	2.440	$u_{r,f}$	2.55	6.5139	
11	Long term drift at zero level	≤	5.0 nmol/mol	1.200	$u_{d,l,z}$	0.69	0.4800	
12	Long term drift at span level	≤	5.0% of max. of certification range	0.240	$u_{d,l,lh}$	0.14	0.0210	
18	Difference sample/calibration port	≤	1.0%	-0.330	$u_{\Delta sc}$	-0.35	0.1191	
21	Converter efficiency	≥	98	99.500	u_{EC}	0.52	0.2735	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
				Combined standard uncertainty	u_c		4.1873	nmol/mol
				Expanded uncertainty	U		8.3746	nmol/mol
				Relative expanded uncertainty	W		8.01	%
				Maximum allowed expanded uncertainty	W_{req}		15	%

Table 40: *Expanded uncertainty from the results obtained in the laboratory tests for analyser 2*

Measuring device: 42iQ — Serial-No.: 1180540004

Measured component: NO_2 — 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	0.250	$u_{r,z}$	0.06	0.0040	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.390	$u_{r,lh}$	0.02	0.0004	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	0.820	$u_{l,lh}$	0.50	0.2452	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.290	u_{gp}	0.72	0.5152	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.271	u_{st}	0.68	0.4650	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000	
8a	Interferent H_2O with 19 mmol/mol	≤	10 nmol/mol (Zero)	0.000	u_{H2O}	-0.02	0.0006	
		≤	10 nmol/mol (Span)	0.000				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.000	$u_{int,pos}$ or $u_{int,neg}$	1.14	1.2902	
		≤	5.0 nmol/mol (Span)	0.200				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	1.800				
		≤	5.0 nmol/mol (Span)	2.400				
9	Averaging effect	≤	7.0% of measured value	-0.400	u_{av}	-0.24	0.0584	
18	Difference sample/calibration port	≤	1.0%	-0.190	$u_{\Delta sc}$	-0.20	0.0395	
21	Converter efficiency	≥	98	98.50	u_{EC}	1.57	2.4618	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
			Combined standard uncertainty		u_c		2.4857	nmol/mol
			Expanded uncertainty		U		4.9714	nmol/mol
			Relative expanded uncertainty		W		4.75	%
			Maximum allowed expanded uncertainty		W_{req}		15	%

Table 41: *Expanded uncertainty from the results obtained in the laboratory and field tests for analyser 2*

Measuring device: 42iQ — Serial-No.: 1180540004

Measured component: NO_2 — 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	0.250	$u_{r,z}$	0.06	0.0040	
2	Repeatability standard deviation at 1h-limit value	≤	3.0 nmol/mol	0.390	$u_{r,lh}$	not considered, as √2*ur,lh = 0,02 < ur,f	-	
3	"lack of fit" at 1h-limit value	≤	4.0% of measured value	0.820	$u_{l,lh}$	0.50	0.2452	
4	Sensitivity coefficient of sample gas pressure at 1h-limit value	≤	8.0 nmol/mol/kPa	0.290	u_{gp}	0.72	0.5152	
5	Sensitivity coefficient of sample gas temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.000	u_{gt}	0.00	0.0000	
6	Sensitivity coefficient of surrounding temperature at 1h-limit value	≤	3.0 nmol/mol/K	0.271	u_{st}	0.68	0.4650	
7	Sensitivity coefficient of electrical voltage at 1h-limit value	≤	0.30 nmol/mol/V	0.000	u_V	0.00	0.0000	
8a	Interferent H_2O with 19 mmol/mol	≤	10 nmol/mol (Zero)	-0.200	u_{H2O}	-0.02	0.0006	
		≤	10 nmol/mol (Span)	0.600				
8b	Interferent CO_2 with 500 µmol/mol	≤	5.0 nmol/mol (Zero)	0.000	$u_{int,pos}$ or $u_{int,neg}$	1.14	1.2902	
		≤	5.0 nmol/mol (Span)	0.200				
8c	Interferent NH_3 mit 200 nmol/mol	≤	5.0 nmol/mol (Zero)	1.800				
		≤	5.0 nmol/mol (Span)	2.400				
9	Averaging effect	≤	7.0% of measured value	-0.400	u_{av}	-0.24	0.0584	
10	Reproducibility standard deviation under field conditions	≤	5.0% of average over 3 months	2.440	$u_{r,f}$	2.55	6.5139	
11	Long term drift at zero level	≤	5.0 nmol/mol	1.200	$u_{d,l,z}$	0.69	0.4800	
12	Long term drift at span level	≤	5.0% of max. of certification range	0.640	$u_{d,l,lh}$	0.39	0.1494	
18	Difference sample/calibration port	≤	1.0%	-0.190	$u_{\Delta sc}$	-0.20	0.0395	
21	Converter efficiency	≥	98	98.500	u_{EC}	1.57	2.4618	
23	Uncertainty of test gas	≤	3.0%	2.000	u_{cg}	1.05	1.0941	
			Combined standard uncertainty		u_c		3.6498	nmol/mol
			Expanded uncertainty		U		7.2996	nmol/mol
			Relative expanded uncertainty		W		6.98	%
			Maximum allowed expanded uncertainty		W_{req}		15	%

8. Recommendations for use in practice

Work in the maintenance interval

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

- Regular visual inspections/telemetric inspections
- Instrument status ok
- No error messages
- Replace the external Teflon filter at the sample gas inlet as required by measurement site conditions;
- Perform zero and reference checks using suitable test gas every two weeks in accordance with standard EN 14211;

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

Environmental Protection/Air Pollution Control

Dipl.-Ing. Martin Schneider

Dipl.-Ing. Guido Baum

Cologne, 2 October 2018
936/21242986/C

9. Bibliography

[1] VDI 4202 part 1: Performance test, declaration of suitability, and certification of point-related measuring systems for gaseous air pollutants of April 2018

[2] European standard EN 14211 Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence, August 2012

[3] Directive 2008/50/EG of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

10. Appendices

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

Annex 2 Manual

DAkkS
Deutsche
Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
Unterzeichnerin der Multilateralen Abkommen
von EA, ILAC und IAF zur gegenseitigen Anerkennung

Akkreditierung

Die Deutsche Akkreditierungsstelle GmbH bestätigt hiermit, dass das Prüflaboratorium

TÜV Rheinland Energy GmbH

mit seinen in der Urkundenanlage aufgeführten Messstellen

die Kompetenz nach DIN EN ISO/IEC 17025:2005 besitzt, Prüfungen in folgenden Bereichen durchzuführen:

Bestimmung (Probenahme und Analytik) von anorganischen und organischen gas- oder partikel-förmigen Luftinhaltsstoffen im Rahmen von Emissions- und Immissionsmessungen; Probenahme von luftgetragenen polyhalogenierten Dibenzo-p-Dioxinen und Dibenzofuranen bei Emissionen und Immissionen; Probenahme von faserförmigen Partikeln bei Emissionen und Immissionen; Ermittlung von gas- oder partikelförmigen Luftinhaltsstoffen mit kontinuierlich arbeitenden Messgeräten; Bestimmung von Geruchsstoffen in Luft; Kalibrierungen und Funktionsprüfungen kontinuierlich arbeitender Messgeräte für Luftinhaltsstoffe einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Feuerraummessungen; Eignungsprüfungen von automatisch arbeitenden Emissions- und Immissionsmesseinrichtungen einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Ermittlung der Emissionen und Immissionen von Geräuschen; Ermittlung von Geräuschen und Vibrationen am Arbeitsplatz; akustische und schwingungstechnische Messungen im Eisenbahnwesen; Bestimmung von Schallleistungspegeln von zur Verwendung im Freien vorgesehenen Geräten und Maschinen nach Richtlinie 2000/14/EG und Konformitätsbewertungsverfahren; Schornsteinhöhenberechnung und Immissionsprognose auf der Grundlage der Technischen Anleitung zur Reinhaltung der Luft und der Geruchsimmissions-Richtlinie und der VDI 3783 Blatt 13; Windenergieanlagen: Bestimmung von Windpotential, Energieerträgen, Standorterträgen und Standortgüte nach EEG, standortbezogenen Turbulenz-charakteristika und Extremwinde; Schallimmissionsprognosen, Schattenwurfimmissionsberechnung und Sichtbarkeits-bestimmung; Probenahme und mikrobiologische Untersuchungen von Nutzwasser gemäß §3 Absatz 8 42. BImSchV; physikalische, physikalisch-chemische und mikrobiologische Untersuchungen von Wasser (Abwasser, Wasser aus Rückkühlwerken sowie raumlufttechnischen Anlagen); Probenahme von Abwasser; mikrobiologische und ausgewählte chemische Untersuchungen gemäß Trinkwasserverordnung; Probenahme von Roh- und Trinkwasser; ausgewählte mikrobiologische Untersuchungen von Bedarfsgegenständen und kosmetischen Mitteln; Probenahme anorganischer faserförmiger Partikel sowie von partikel- und gasförmigen luftverunreinigenden Stoffen in der Innenraumluft; ausgewählte mikrobiologische Untersuchungen in Innenräumen; Ermittlung von Aerosolen und Faserstäuben, anorganischen und organischen Gasen und Dämpfen sowie ausgewählten Parametern und/oder in ausgewählten Gebieten bei Arbeitsplatzmessungen gemäß Gefahrstoffverordnung §7, Abs. 10; Modul Immissionsschutz

Die Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 02.08.2018 mit der Akkreditierungsnummer D-PL-11120-02-00 und ist gültig bis 10.12.2022. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 55 Seiten.

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

Berlin, 02.08.2018

Valbuena
Im Auftrag Dipl.-Ing. Andrea Valbuena
Abteilungsleiterin

Siehe Hinweise auf der Rückseite

Figure 12: Certificate of accreditation according to EN ISO/IEC 17025:2005

Deutsche Akkreditierungsstelle GmbH

Standort Berlin
Spittelmarkt 10
10117 Berlin

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

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

Die auszugsweise Veröffentlichung der Akkreditierungsurkunde bedarf der vorherigen schriftlichen Zustimmung der Deutsche Akkreditierungsstelle GmbH (DAkkS). Ausgenommen davon ist die separate Weiterverbreitung des Deckblattes durch die umseitig genannte Konformitätsbewertungsstelle in unveränderter Form.

Es darf nicht der Anschein erweckt werden, dass sich die Akkreditierung auch auf Bereiche erstreckt, die über den durch die DAkkS bestätigten Akkreditierungsbereich hinausgehen.

Die Akkreditierung erfolgte gemäß des Gesetzes über die Akkreditierungsstelle (AkkStelleG) vom 31. Juli 2009 (BGBl. I S. 2625) sowie der Verordnung (EG) Nr. 765/2008 des Europäischen Parlaments und des Rates vom 9. Juli 2008 über die Vorschriften für die Akkreditierung und Marktüberwachung im Zusammenhang mit der Vermarktung von Produkten (Abl. L 218 vom 9. Juli 2008, S. 30).
Die DAkkS ist Unterzeichnerin der Multilateralen Abkommen zur gegenseitigen Anerkennung der European co-operation for Accreditation (EA), des International Accreditation Forum (IAF) und der International Laboratory Accreditation Cooperation (ILAC). Die Unterzeichner dieser Abkommen erkennen ihre Akkreditierungen gegenseitig an.

Der aktuelle Stand der Mitgliedschaft kann folgenden Webseiten entnommen werden:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Figure 12: Certificate of accreditation according to EN ISO/IEC 17025:2005 - page 2

Annex 1:

Manual

thermo scientific

42iQ
Instruction Manual

$NO-NO_2-NO_x$ Analyzer

117435-00 • 15Jan2018

Thermo Fisher SCIENTIFIC

Contents

Chapter 1
Introduction

The Thermo Scientific™ 42iQ NO-NO_2-NO_x Analyzer utilizes chemiluminescence technology to measure the amount of nitrogen oxides in the air from sub-ppb levels up to 100 ppm.

This analyzer is a single chamber, single photomultiplier tube design that cycles between the NO and NO_x modes.

The 42iQ Analyzer has independent outputs for NO, NO_2 and NO_x that can be calibrated separately. If required, the instrument can be operated continuously in either the NO or NO_x modes allowing for response times of less than five seconds. Dual range, auto range, temperature correction and pressure correction are standard features.

iQ Series Instrument Platform

The iQ Series Instrument Platform is a smart environmental monitoring solution for ambient and source gas analysis that affords greater control over instrument performance and data availability.

- Distributed Measurement and Control (DMC) module design simplifies serviceability. Each DMC module contains its own microprocessor control enabling functional performance validation at the module level.
- Built-in predictive diagnostics and preventive maintenance schedules identify problems before they occur. The iQ Series platform sends email notifications directly to Thermo Fisher Scientific's world class service support team or locally identified addressees in order to proactively communicate analyzer performance conditions and identify spare parts needs before an operational concern arises.
- The iQ Series platform supports Modbus, streaming and VNC protocols over serial and Ethernet as well as analog and digital I/O for easy integration into most data management systems.
- Three standard USB ports afford convenient data download capability as well as the ability to connect additional hardware, such as a computer keyboard or mouse.
- The iQ Series GUI runs on a 7" color touchscreen display. The GUI is highly flexible and can be customized to enable a tailored

experience to simplify daily operations. Custom designed ePort software allows remote access to the analyzer with a PC. The ePort control mirrors the same GUI look and feel as the instrument touchscreen providing a speedy and familiar operational experience.

Figure 1–1. 42iQ Front

Principle of Operation

The 42iQ operates on the principle that nitric oxide (NO) and ozone (O_3) react to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration. Infrared light emission results when NO_2 molecules decay to lower energy states. Specifically:

$$NO + O_3 \rightarrow NO_2 + O_2 + h\nu$$

Nitrogen dioxide (NO_2) must first be transformed into NO before it can be measured using the chemiluminescent reaction. NO_2 is converted to NO by a molybdenum NO_2-to-NO converter heated to about 325 °C (the optional stainless steel converter is heated to 625 °C).

The ambient air sample is drawn into the 42iQ through the *sample* bulkhead, as shown in Figure 1–2. The sample flows through a capillary, and then to the mode solenoid valve. The solenoid valve routes the sample either straight to the reaction chamber (NO mode) or through the NO_2-to-NO converter and then to the reaction chamber (NO_x mode). The reaction chamber pressure is measured to infer the sample flow. Pressure deviations outside of the acceptable range are reported as a fault.

Dry air enters the 42iQ through the permeation dryer, passes through a flow switch, and then through a silent discharge ozonator. The ozonator generates the ozone needed for the chemiluminescent reaction. At the reaction chamber, the ozone reacts with the NO in the sample to produce excited NO_2 molecules. A photomultiplier tube (PMT) housed in a thermoelectric cooler detects the luminescence generated during this reaction. From the reaction chamber, the exhaust travels through the ozone (O_3) converter to the pump, and is released through the vent.

The NO and NO_x concentrations calculated in the NO and NO_x modes are stored in memory. The difference between the concentrations is used to calculate the NO_2 concentration. The 42iQ outputs NO, NO_2, and NO_x concentrations to the front panel display and the analog outputs, and also makes the data available over the serial or Ethernet connection.

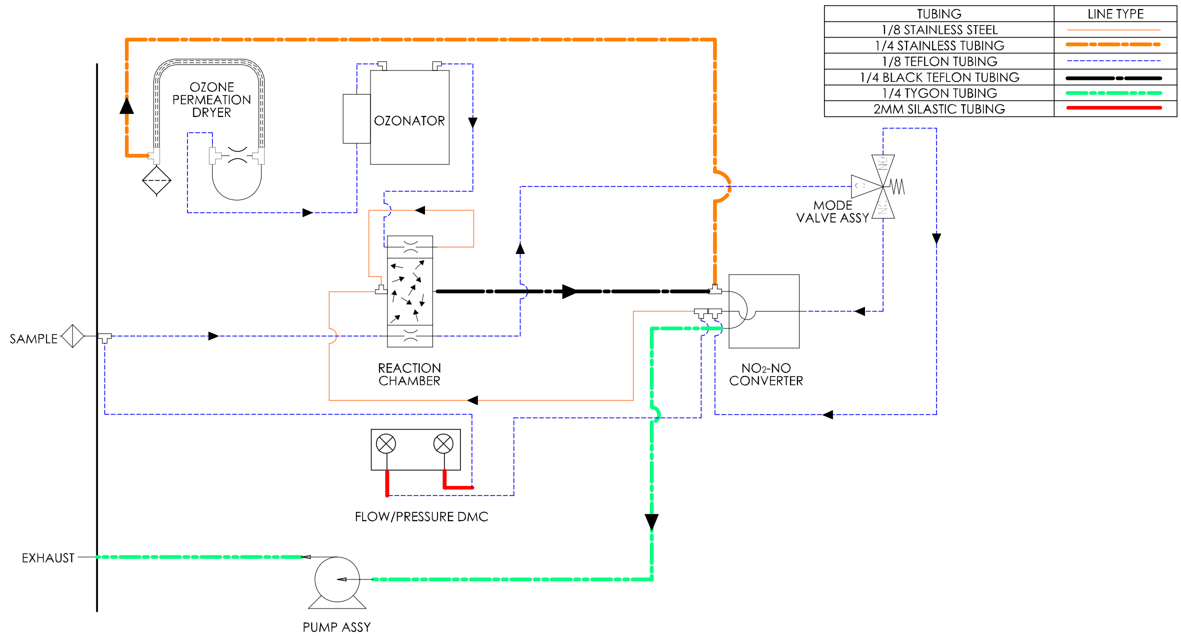


Figure 1–2. 42iQ Flow Schematic

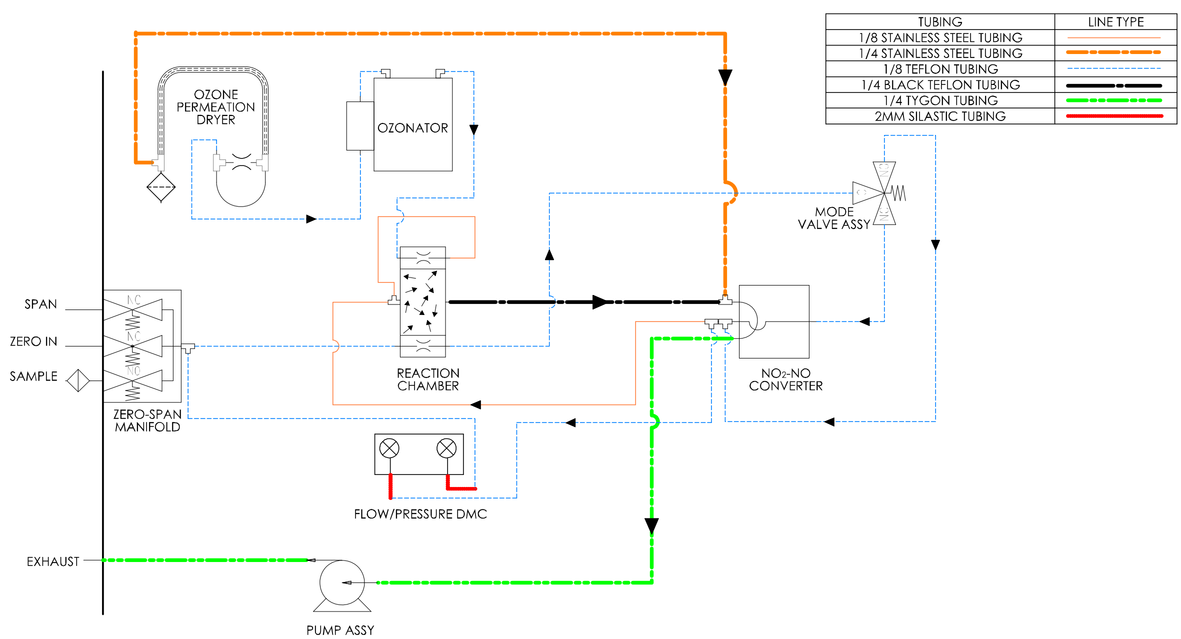


Figure 1–3. 42iQ Flow Schematic with Zero Span

Specifications

Table 1–1 lists the specifications for the 42iQ.

Table 1–1. 42iQ Specifications

Range	0–20 ppm 0–30 mg/m³
Extended Ranges	0–100 ppm 0–150 mg/m³
Zero Noise	0.20 ppb RMS (60 second averaging time)
Detection Limit	0.40 ppb (60 second averaging time)
Zero Drift	<0.40 ppb (24 hour)
Span Drift	±1% full-scale (1 week)
Response Time	40 sec (10 second averaging time) 80 sec (60 second averaging time) 300 sec (300 second averaging time)
Linearity	±1% full-scale
Flow Rate	0.6–0.8 lpm
Operating Temperature Range	0–40 °C
Power Requirements	100–240 VAC 50/60 Hz 275 Watts
Physical Dimensions	24 in (D) x 16.75 in (W) x 8.72 in (H) [609 mm (D) 425.45 mm (W) x 221.48 mm (H)]
Weight	40 lbs
Analog I/O	4 Isolated Voltage Inputs 0–10 V 6 Isolated Analog Voltages Outputs, with 4 selectable ranges 6 Isolated Analog Current Outputs, with 2 selectable ranges
Digital I/O	16 Digital Inputs (TTL) 8 Solenoid Driver Outputs 10 Digital Reed Relay Contact Outputs
Serial Ports	1 RS-232/485 port 1 RS-485 External Accessory port
Other Ports	3 Full Speed USB ports (one in front, two in rear) 1 Gigabit Ethernet port
Communication Protocols	MODBUS, Streaming
Approvals and Certifications	CE, TUV-SUD Safety, EPA

Table 1–2. 42iQ Optional Permeation Oven Specifications

Temperature Control	Three user selectable set points: 30, 35, 45 °C
Temperature Stability	± 0.1 °C
Warm-up Time	1 hour (permeation device can take 24 to 48 hours to stabilize)
Carrier Gas Flow	≈ 700 scc/min
Chamber size	Accepts permeation tubes up to 9 cm in total length; 1 cm in diameter
Physical Dimensions	Contained inside the 42iQ
Power Requirements	24 VDC, 50 watts (in addition to the standard 42iQ)
Weight	Approximately five pounds (in addition to standard 42iQ)

Dimensions

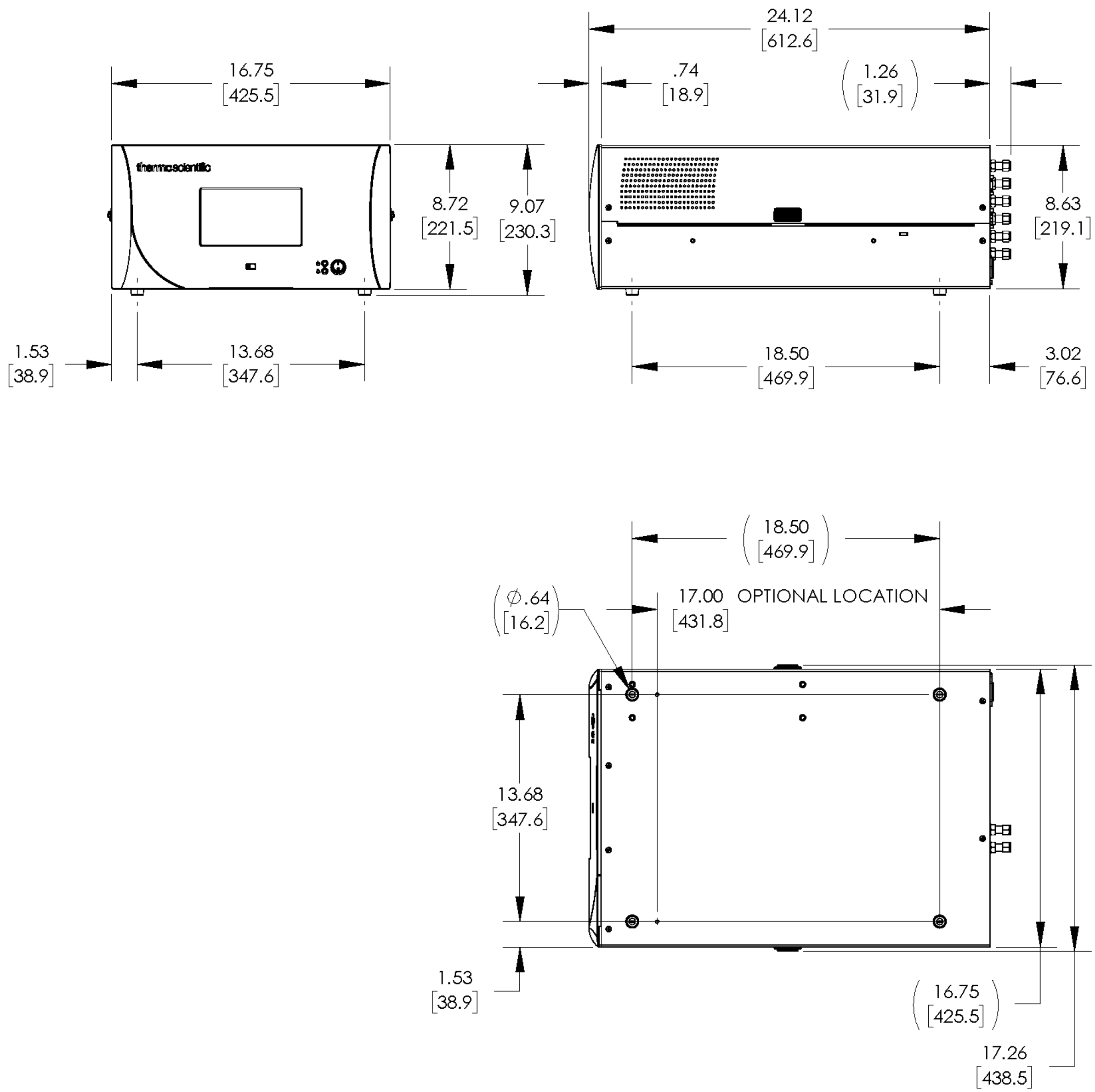


Figure 1–4. Bench Mount Assembly (dimensions in inches [mm])

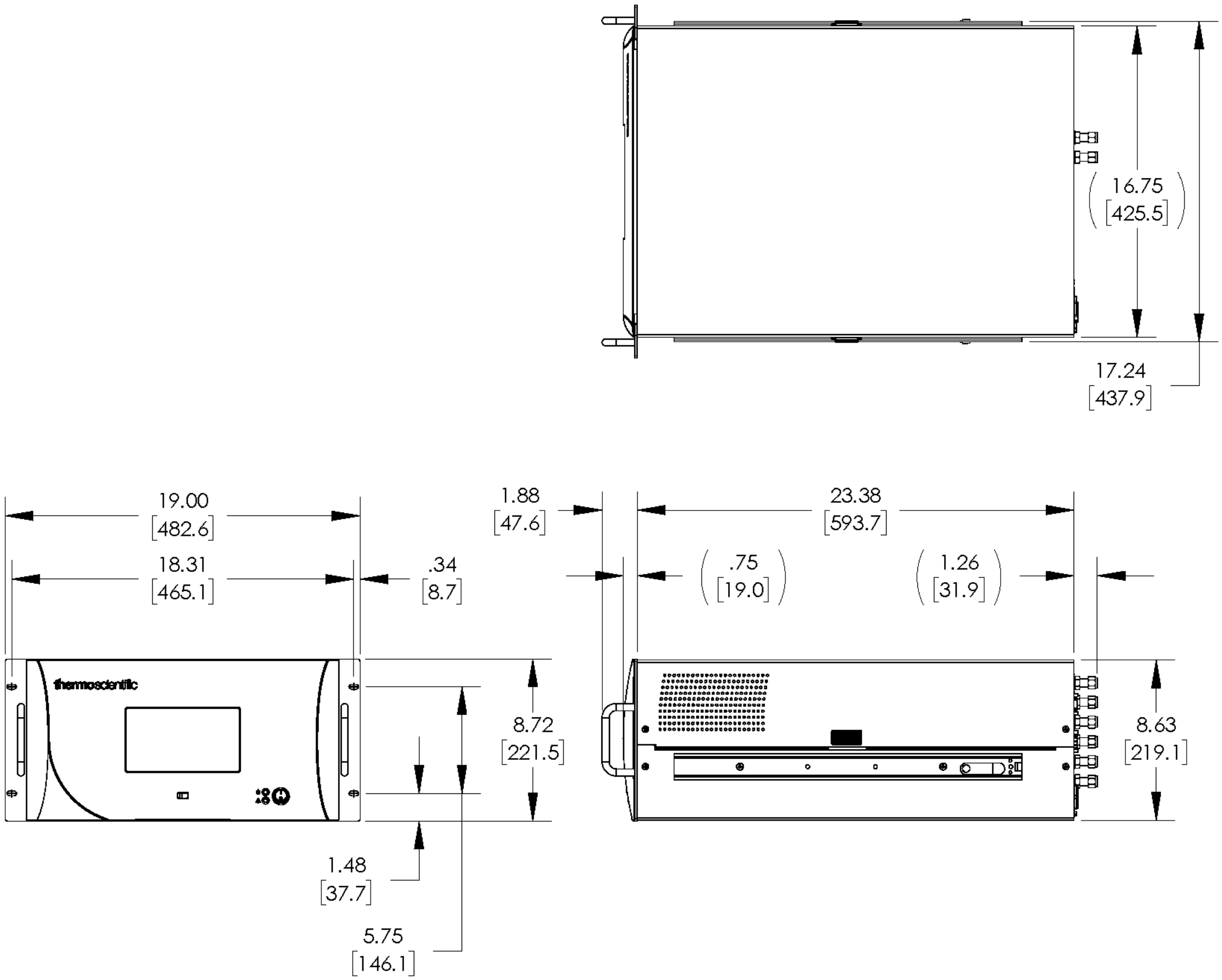


Figure 1–5. Rack Mount Assembly (dimensions in inches [mm])

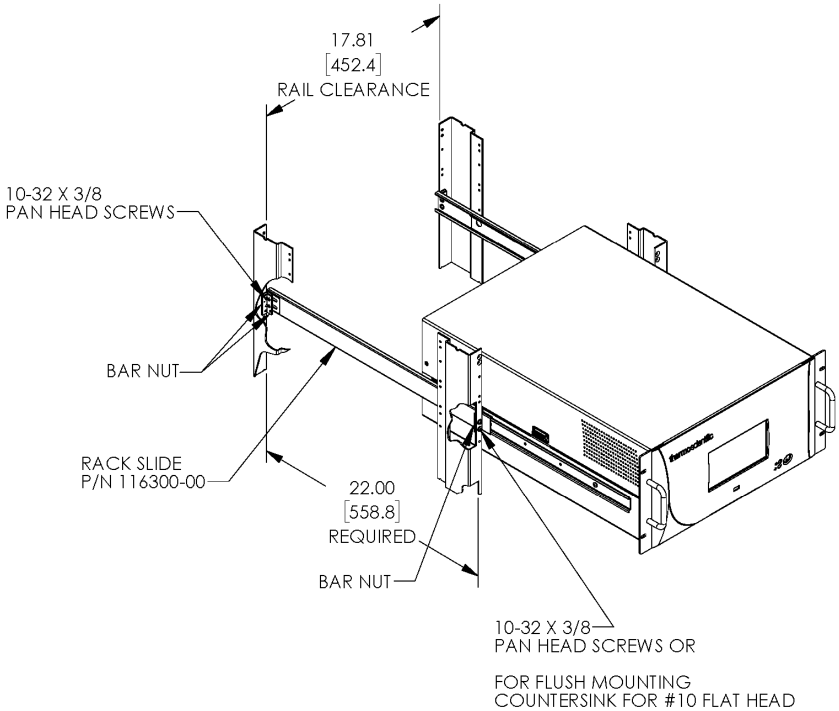


Figure 1–6. Rack Mount Requirements

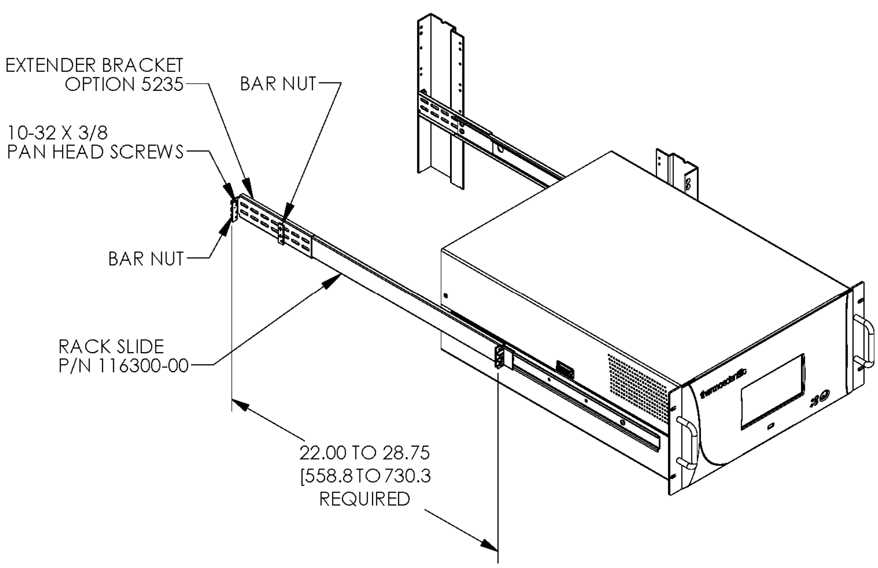


Figure 1–7. Rack Requirements Part 2

Chapter 2
Installation and Setup

Installation and Setup describes how to unpack, setup, and start-up the instrument. The installation should always be followed by instrument calibration as described in the "Calibration" chapter of this manual.

Equipment Damage Do not attempt to lift the instrument by the cover or other external fittings. ▲

Unpacking and Inspection

The 42iQ is shipped complete in one container. If there is obvious damage to the shipping container when you receive the instrument, notify the carrier immediately and hold for inspection. The carrier is responsible for any damage incurred during shipment.

Use the following procedure to unpack and inspect the instrument.

1. Remove the instrument from the shipping container and set it on a table or bench that allows easy access to both the front and rear.

2. Remove the cover to expose the internal components. (See "Figure 2–1" on page 2-2.)

3. Check for possible damage during shipment.

4. Check that all connectors and circuit boards are firmly attached.

5. Re-install the cover.

6. Remove any protective plastic material from the case exterior.

Cover Removing and Replacing

Use the following procedure to remove and replace the cover.

Equipment required:

Phillips screwdriver, #2

1. Unfasten the four 8-32 screws securing the cover (shipping screws).

2. Press in both latches located on top cover and hold while pulling up to remove. Set upright.

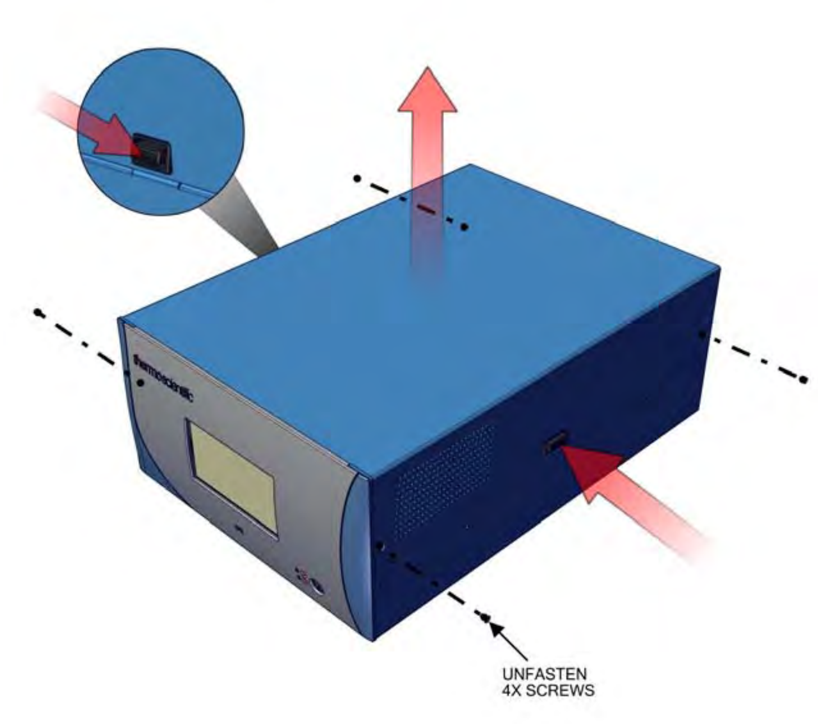


Figure 2–1. Removing the Cover

3. To replace, align cover and drop in. Latches will automatically snap in place.

Mounting Options

The instrument can be installed in the following configurations:

- Bench Mount
- Rack Mount

Bench Mount

Positioned on bench, includes installing feet. See Figure 2–2.

Equipment required:

Slot drive, 5/16-inch

1. Fasten feet in position 1 or 2 to fit to the desired depth.

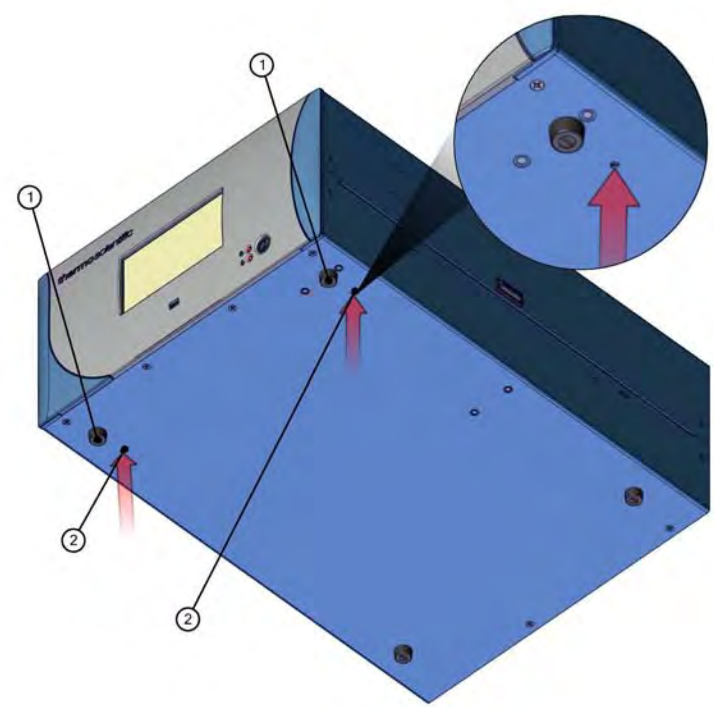


Figure 2–2. Installing Feet

Rack Mount

Mounting in a rack includes removing the front panel and installing ears and handles.

Equipment required:

Phillips drive, #2

1. Start by gripping from the top corners of the front panel and pull outwards.

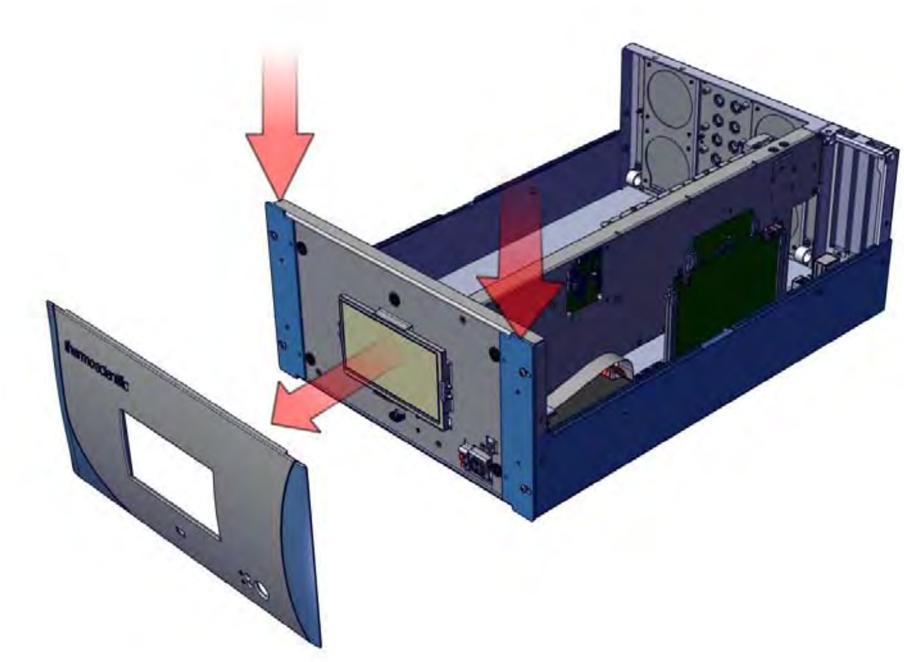


Figure 2–3. Removing the Front Panel

2. Unfasten the four 8-32 x 3/16-inch pan head screws.

3. Slide ears outwards.

4. Use the same four 8-32 x 3/16-inch pan head screws to secure it.

5. Install the handles with the four 8-32 x 3/16-inch flat head screws.

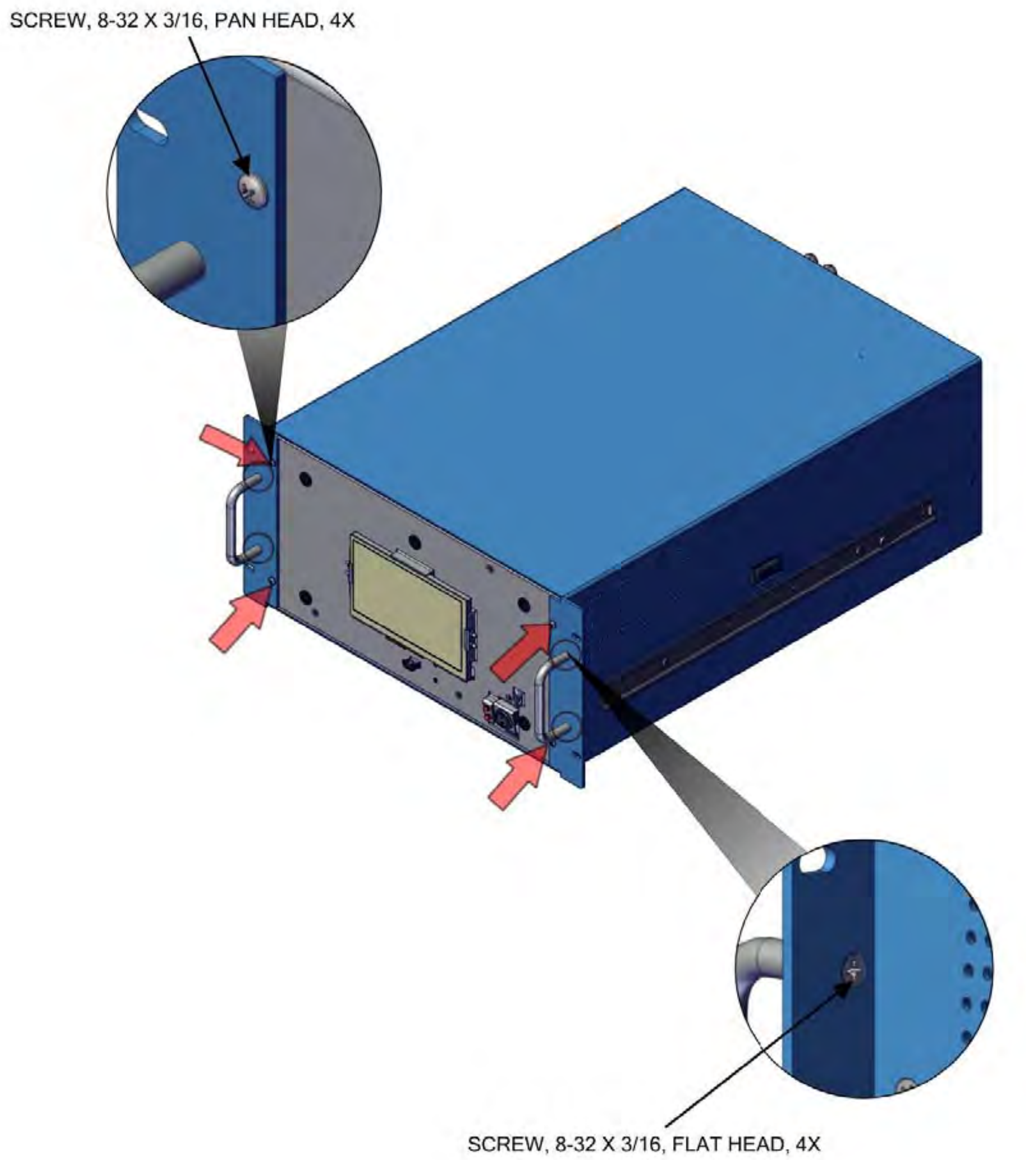


Figure 2–4. Installing Ears and Handles

Setup Procedure

Use the following procedure to setup the instrument:

1. Connect the sample line to the SAMPLE bulkhead on the rear panel (Figure 2–5). Ensure that the sample line is not contaminated by dirty, wet, or incompatible materials. All tubing should be constructed of PTFE, 316 stainless steel, borosilicate glass, or similar tubing with an OD of 1/4-inch and a minimum ID of 1/8-inch. The length of the tubing should be less than 10 feet.

Note Gas must be delivered to the instrument free of particulates. It may be necessary to use the PTFE particulate filter as described in "PTFE Particulate Filter" on page 9-26. ▲

Note Gas must be delivered to the instrument at atmospheric pressure. It may be necessary to use an atmospheric bypass plumbing arrangement as shown in Figure 2–6 if gas pressure is greater than atmospheric pressure. ▲

2. Connect the EXHAUST bulkhead to a suitable vent. The exhaust line should be 1/4-inch OD with a minimum ID of 1/8-inch. The length of the exhaust line should be less than 10 feet. Verify that there is no restriction in this line.

3. If the optional zero/span solenoid valves are installed, connect a source of NO_x-free air to the ZERO IN bulkhead, and connect a source of NO span gas to the SPAN bulkhead.

4. Connect a suitable recording device to the rear panel connector. For detailed information about connecting to the instrument, refer to:

   "Connecting External Devices" on page 9-1

   Communications > "Analog I/O" on page 3-64 and "Digital I/O" on page 3-66.

5. Plug the instrument into an outlet of the appropriate voltage and frequency.

Note If instrument is equipped with an internal permeation oven, refer to Chapter 9, "Optional Equipment" for setup instructions. ▲

WARNING The 42iQ is supplied with a three-wire grounding cord. Under no circumstances should this grounding system be defeated. ▲

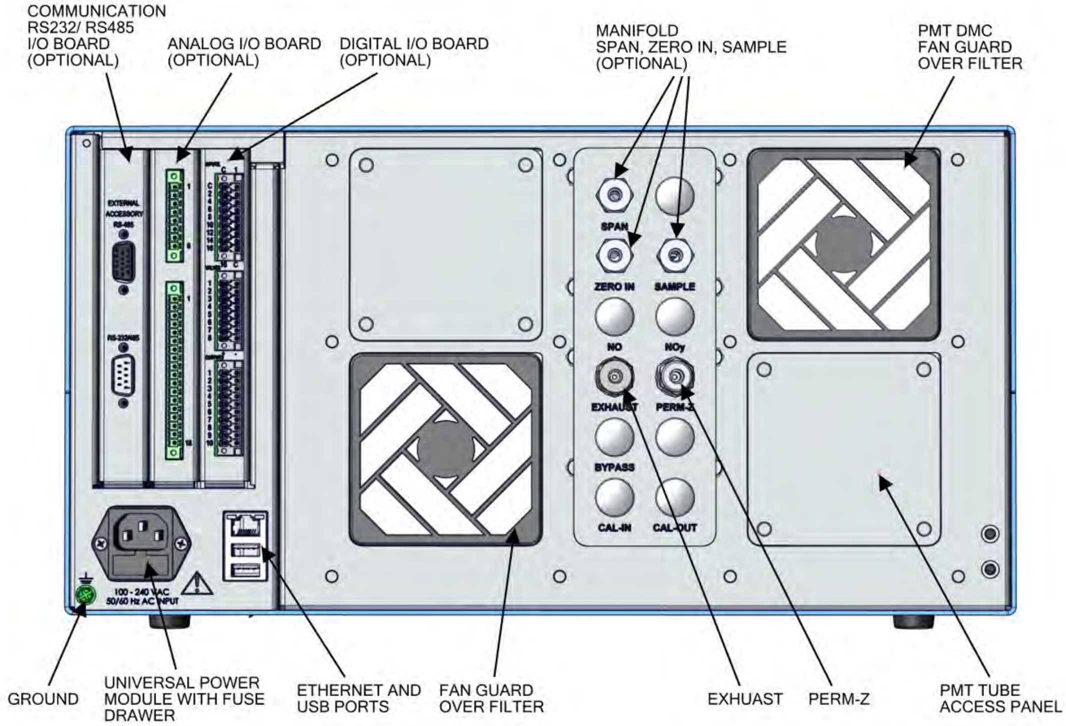


Figure 2–5. 42iQ Rear Panel

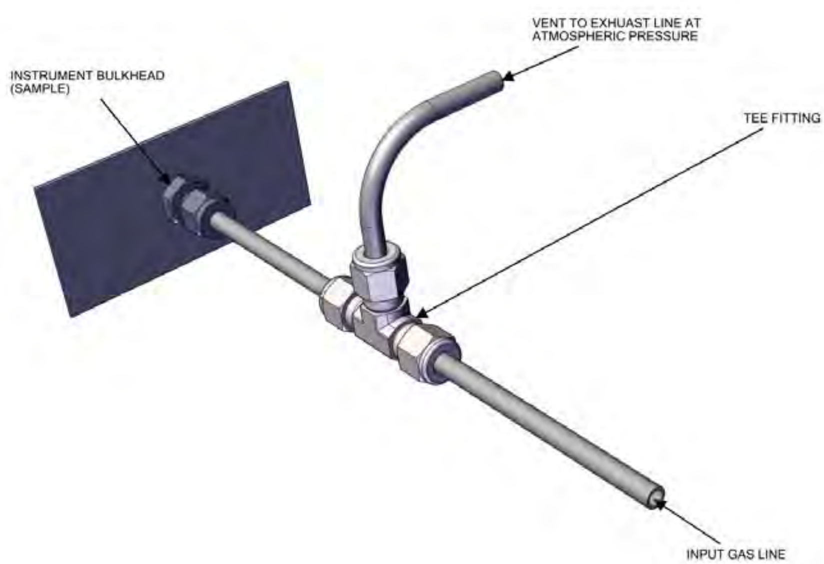


Figure 2–6. Atmospheric Dump Bypass Plumbing

Startup

Use the following procedure when starting the instrument.

1. Turn the power ON.

2. Allow 90 minutes for the instrument to stabilize.

3. Set instrument parameters such as operating ranges and averaging times to appropriate settings. For more information about instrument parameters, see the "Operation" chapter.

4. Before beginning the actual monitoring, perform a multipoint calibration as described in the "Calibration" chapter.

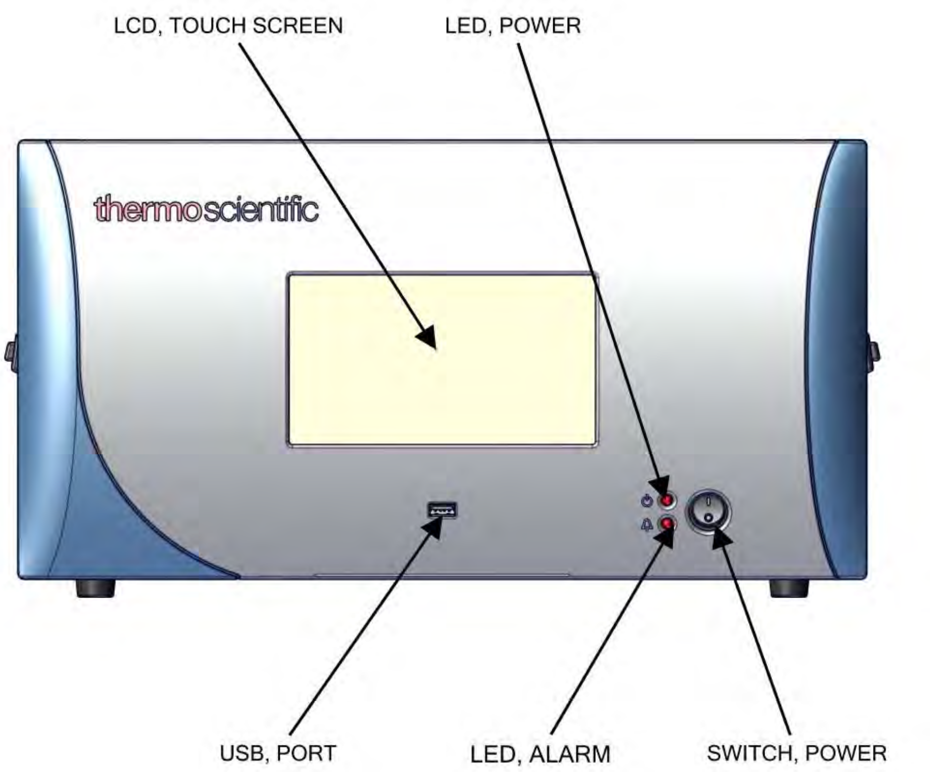


Figure 2–7. Front Panel and Touchscreen Display

Chapter 3
Operation

This chapter describes the functionality of the touchscreen user interface.

Instrument Display

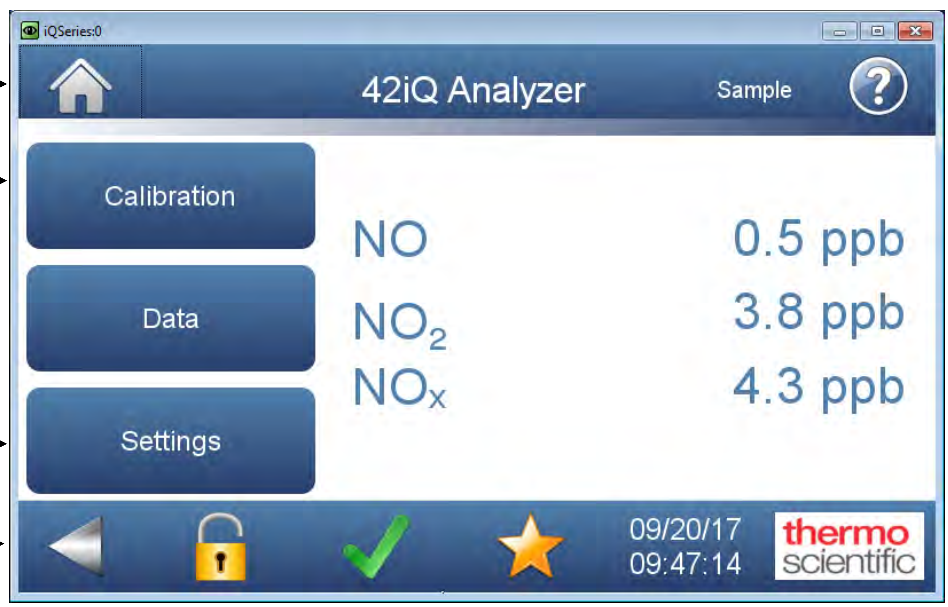
The Instrument Display consists of a Title Bar, a User Interface, and a Status Bar. The Title Bar, located at the top, includes the Home button, instrument name, instrument gas mode, and Help button. The User Interface, located in the middle, is where the Home Screen and all other screens are accessed. The Home Screen has three Main Menu buttons, located on the left side, which include Calibration, Data, and Settings, while the user interface to the right of the buttons displays the chemical names, concentration values and units. The Status Bar, located at the bottom, includes the Back button, Access Levels, Health Check, Favorites, Date and Time, and Contact Information.

Home Screen (single range mode)

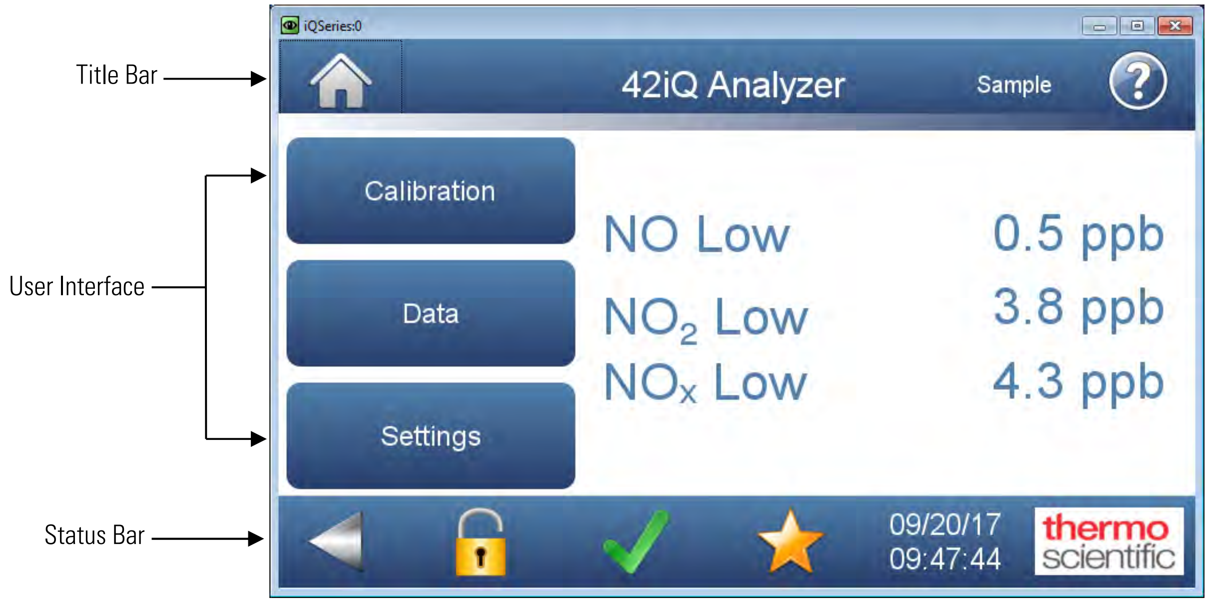
Title Bar

User Interface

Status Bar



Home Screen (dual or auto range mode)



The Instrument Display contains the following information:

- Title Bar:
  - *Home button:* When pressed, it brings you to the Home Screen.
  - *Title Text:* Displays instrument name when in the Home Screen. Displays the chemical name, current concentration reading and unit when in all other screens. When unit is pressed, it brings you to the unit selection screen.
  - *Gas Mode button:* Displays current gas mode of the instrument. When pressed, brings you to the Gas Mode selection screen.
  - *Help button:* When pressed, brings you to the help screens.
- User Interface:
  - *Calibration button:* Allows the user to calibrate the instrument, setup automatic calibrations, and view calibration data.
  - *Data button:* Allows the user to view, graph, stream, and analyze data.
  - *Settings button:* Shows real-time status and alarms, also predictive diagnostics and maintenance history. Contains controls for operating the instrument, communications, and sets instrument options.
  - *Concentration*: When in single mode, displays NO, NO_2, and NO_x concentrations in big, bold characters, depending on operating mode. When in dual or auto mode, displays either high range or low range values based on the range setting.
- Status Bar:
  - *Back button:* When pressed, it displays the previous screen.
  - *Access Levels button:* Allows the user to set security access levels, and allows/restricts access to functionality depending on the selected access level.
  - *Health Check button:* Brings the user to the Health Check screen.
  - *Favorites button:* Allows user-selectable favorite buttons. To add to the favorites screen, user presses the desired screen button for 2 seconds. The user will be directed to the favorites screen where the user chooses the button position. To remove a favorite button from the favorites screen, press and hold button for 2 seconds.
  - *Clock:* Displays current date and time.

- *Thermo Scientific Information button:* Shows contact information.

Main Menus and Keypads

The Main Menu buttons, located on the Home Screen, contains three submenus. Each submenu contains related instrument settings. This chapter describes each submenu and screen in detail. Refer to the appropriate sections for more information.

Calibration

Calibrate Backgrounds
- Calibrate NO Background
- Calibrate NOx Background

Calibrate Span Coefficients
- Calibrate NO Span Coefficient
- Calibrate NO2 Span Coefficient
- Calibrate NOx Span Coefficient

Zero/Span Schedule

- Advanced Calibration
- Manual Calibration
  - Adjust Backgrounds
    - Adjust NO Background
    - Adjust NOx Background
  - Adjust Coefficients
    - Adjust NO Span Coefficient
    - Adjust NO2 Span Coefficient
    - Adjust NOx Span Coefficient
  - Reset Bkg and Span Coef
- Calibration History

Data

View Data Log (Last Hour)
- Graph

View Data Log (Last 24 Hours)
- Graph

View Data (User Defined Time)
- Start Time
  - End Time – View Data
    - Graph

Advanced Data
- Data Logging Setup
- Streaming Data Setup

User Contact Information

Update Bootloader

Settings

Health Check
- Status and Alarms
- Predictive Diagnostics
- Maintenance
- File Sharing and Support
- Firmware Version

- Measurement Settings
- Averaging Time
- Range Mode Selection
- Range Settings
- Gas Mode
- Gas Units
- Dilution Ratio
- Advanced Measurement
  - Reaction Chamber Settings
  - Perm Oven Settings (Optional)
  - Auto/Manual Mode
  - Extended Ranges
  - Compensation
  - Pressure Calibration

Communication Settings

Instrument Settings
- Title Bar Setup
- Instrument Setpoints
- Alarm Setpoints
- Ozonator Safety
- PMT Supply
- Ozonator Supply
- Display Setup
- Clock
- Language
- Pump Power

Configuration

Security Access Levels

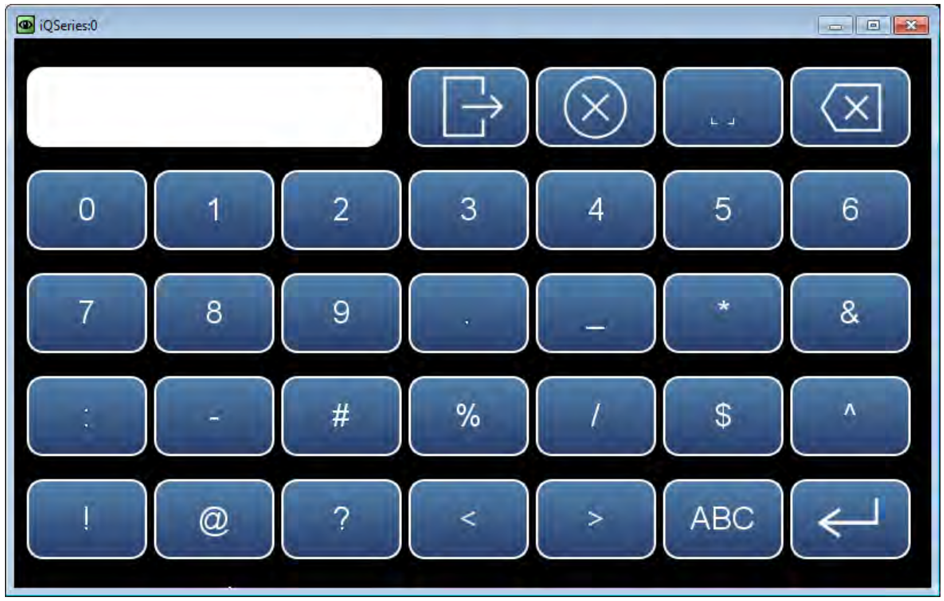
USB Drive
- Firmware Update Via USB Drive
- Download Data to USB Drive
- Change USB Password

Numeric Keypad

User enters a value into the box using the number keypad. When the user needs to change a value, such as for flow rates, temperatures or pressures, the keypad screen will automatically display. Initially, the box above the keypad will display the current value. Enter a new value using the keypad, and then select the **Enter** button to set the new value or press the **Cancel** button to exit the keypad screen and return to the previous screen without saving the value.

Alphanumeric Keypad

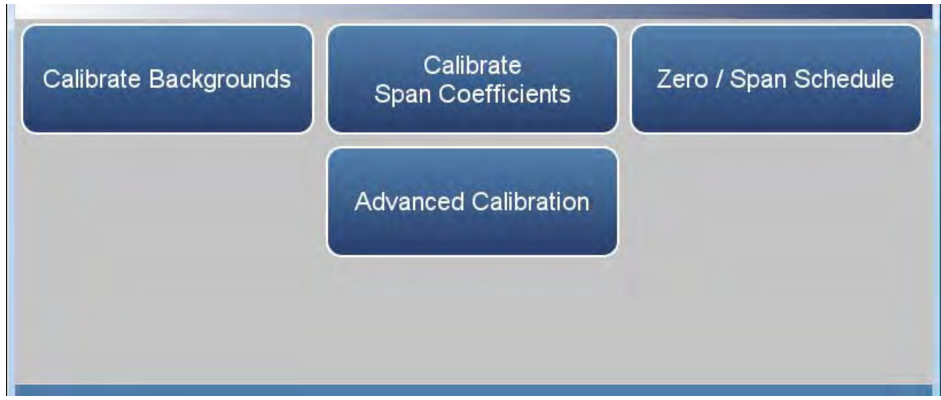
User enters a value into the box using the keypad. When the user needs to change an alphanumeric value, this keypad will automatically display. Initially, the box above the keypad will display the current value. Enter a new value using the keypad, and then select the **Enter** button to set the new value or press the **Cancel** button to exit the keypad screen and return to the previous screen without saving the value. The alphanumeric keypad is only available when the user needs to enter alphabet characters.


iQSeries:0
0
1
2
3
4
5
6
7
8
9
.
_
*
&
:
-
#
%
/
$
^
!
@
?
<
>
ABC

Calibration

The Calibration screen allows the user to calibrate the system, setup automatic calibrations, and view calibration data. See Chapter 4 "Calibration" for further instructions on how to run a calibration.

Home Screen>Calibration



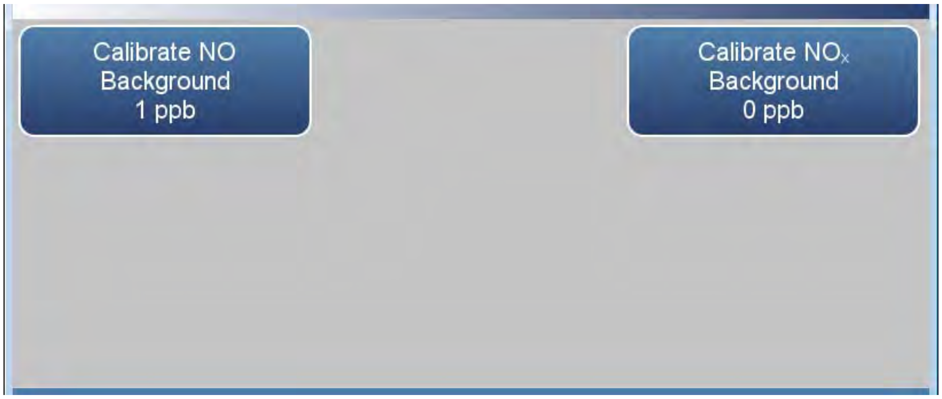
The Calibration screen contains the following information:

- *Calibrate Backgrounds:* Sets the NO and NO_x reading to zero.
- *Calibrate Span Coefficients:* Sets the NO, NO_2, and NO_x span coefficients when in single mode.
- *Zero/Span Schedule:* Programs the instrument to perform fully automated zero and span checks or adjustments.
- *Advanced Calibration:* Calibrates the instrument using manual zero/span calibration and provides calibration history.

Calibrate Backgrounds

The Calibrate Backgrounds screen is used to calibrate the instrument zero background of NO and NO_x.

Home Screen>Calibration>Calibrate Backgrounds



The Calibrate Backgrounds screen contains the following information:

- *Calibrate NO Background:* Sets the NO background to zero.
- *Calibrate NO_x Background:* Sets the NO_x background to zero.

Calibrate NO and NO_x Background

The Calibrate NO and NO_x Background screens are used to calibrate the instrument zero background. Before making an adjustment, be sure the analyzer samples zero air for at least 5 minutes.

It is important to note the averaging time when calibrating. The longer the averaging time the more precise the calibration results. To achieve maximum precision, allow the instrument to stabilize each time input gas is changed and set the averaging time to 300-second averaging.

Home Screen>Calibration>Calibrate NO Background

Home Screen>Calibration>Calibrate NO_x Background

The Calibrate Background screen contains the following information:

- *Target NO Concentration:* Read only. Displays what the NO concentration value will become when the calibrate button is pressed.
- *Current NO Concentration:* Read only. Displays what the current NO concentration is.
- *Current NO Background:* Read only. Displays what the current user-set NO background is.

- *Calculated NO Background:* Read only. Displays what the user-set NO background will become when the calibrate button is pressed.
- *Calibrate:* When pressed, updates the background value, making the concentration go to 0.0.
- *Target NO_x Concentration:* Read only. Displays what the NO_x concentration value will become when the calibrate button is pressed.
- *Current NO_x Concentration:* Read only. Displays what the current NO_x concentration is.
- *Current NO_x Background:* Read only. Displays what the current user-set NO_x background is.
- *Calculated NO_x Background:* Read only. Displays what the user-set NO_x background will become when the calibrate button is pressed.
- *Calibrate:* When pressed, updates the background value, making the concentration go to zero.

Calibrate Span Coefficients

The Calibrate Span Coefficients screens are used to calibrate the NO, NO_2, and NO_x span coefficients.

The following screens show the calibration screen in single range mode and dual or auto range mode. The dual and auto range modes have two span factors (high and low). This allows each range to be calibrated separately. When calibrating the instrument in dual or auto range, be sure to use a low span gas to calibrate the low range and a high span gas to calibrate the high range. For more information about range modes, see "Range Mode Selection" on page 3-80.

It is important to note the averaging time when calibrating. The longer the averaging time the more precise the calibration results. To achieve maximum precision, allow the instrument to stabilize each time input gas is changed and set the averaging time to 300-second averaging.

Home Screen>Calibration>Calibrate Span Coefficients (single range mode)

Home Screen>Calibration>Calibrate Span Coefficients (dual or auto range mode)

The Calibrate Coefficients screen contains the following information:

- *Calibrate NO Span Coefficient:* Sets the NO span coefficient when in single range mode.
- *Calibrate High Range NO Span Coefficient:* Sets the high range NO span coefficient when in dual or auto range mode.
- *Calibrate Low Range NO Span Coefficient:* Sets the low range NO span coefficient when in dual or auto range mode.
- *Calibrate NO_2 Span Coefficient:* Sets the NO_2 span coefficient when in single range mode.
- *Calibrate High Range NO_2 Span Coefficient:* Sets the high range NO_2 span coefficient when in dual or auto range mode.
- *Calibrate Low Range NO_2 Span Coefficient*: Sets the low range NO_2 span coefficient when in dual or auto range mode.
- *Calibrate NO_x Span Coefficient:* Sets the NO_x span coefficient when in single range mode.
- *Calibrate High Range NO_x Span Coefficient:* Sets the high range NO_x span coefficient when in dual or auto range mode.
- *Calibrate Low Range NO_x Span Coefficient:* Sets the low range NO_x span coefficient when in dual or auto range mode.

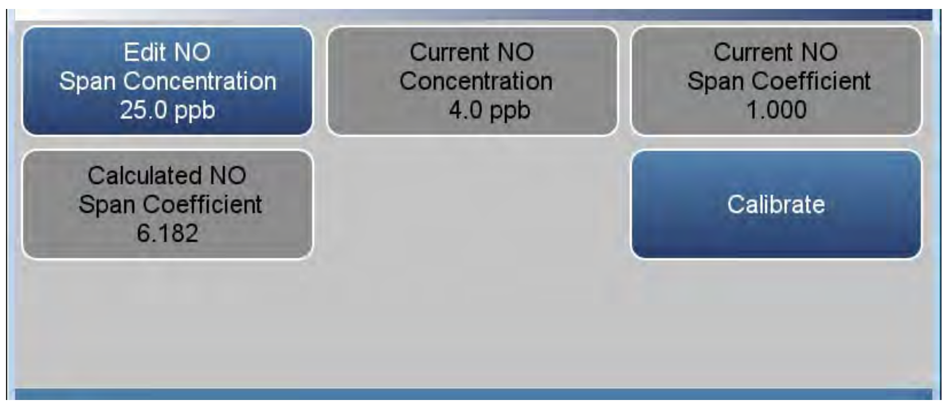
Calibrate NO, NO_2, and NO_x Span Coefficient

The Calibrate NO, NO_2, and NO_x Span Coefficient screens are used to enter span concentrations and calibrate the NO, NO_2, and NO_x span coefficients. The NO span coefficient is calculated, stored, and used to correct the current reading. All calibration screens function the same way. Therefore, the following example of the NO screen applies to the NO_2 and NO_x calibration screens as well.

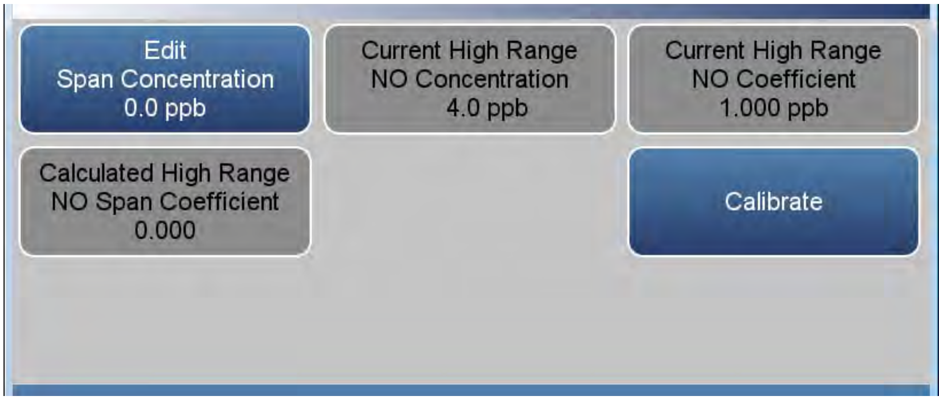
The following screens are shown in single range mode and dual or auto range mode. In dual or auto range modes, “High” or “Low” is displayed to indicate the calibration of the high or low coefficient. The Calibrate High Span Coefficient and Calibrate Low Span Coefficient screens function the same way.

It is important to note the averaging time when calibrating. The longer the averaging time the more precise the calibration results. To achieve maximum precision, allow the instrument to stabilize each time input gas is changed and set the averaging time to 300-second averaging.

Home Screen>Calibration>Calibrate Span Coefficient (single range mode)



Home Screen>Calibration>Calibrate High Range Coefficient (dual or auto range mode)



The Calibrate NO, NO_2, and NO_x Span Coefficient screens contain the following information:

- *Edit NO Span Concentration:* User enters the NO span concentration when in single range mode.
- *Edit Span Concentration:* User enters the high range or low range span concentration when in dual or auto range mode.
- *Current NO Concentration.:* Read only. Current NO concentration reading when in single range mode.
- *Current High Range NO Concentration:* Read only. Current high range NO concentration reading when in dual or auto range mode.
- *Current Low Range NO Concentration:* Read only. Current low range NO concentration reading when in dual or auto range mode.
- *Current NO Span Coefficient:* Read only. Displays the current user-set NO span coefficient when in single range mode.
- *Current High Range NO Coefficient:* Read only. Displays the current user-set high range NO span coefficient when in dual or auto range mode.
- *Current Low Range NO Coefficient:* Read only. Displays the current user-set low range NO span coefficient when in dual or auto range mode.
- *Calculated NO Span Coefficient:* Read only. After the “Edit NO Span Concentration” value is entered, the new calculated NO span coefficient is displayed.
- *Calculated High Range NO Span Coefficient:* Read only. After the “Edit Span Concentration” value is entered, the new calculated high range NO span coefficient is displayed.

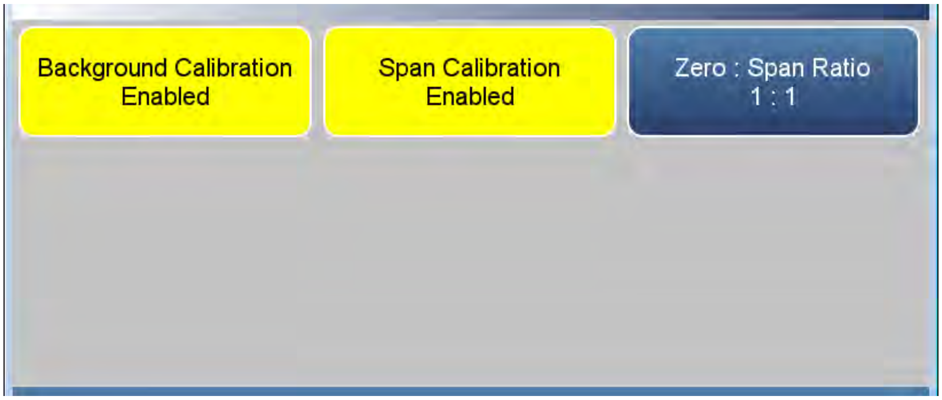
- *Calculated Low Range NO Span Coefficient:* Read only. After the "Edit Span Concentration" value is entered, the new calculated low range NO span coefficient is displayed.
- *Calibrate:* When pressed, updates the coefficient and the concentration should match the span concentration.

Zero/Span Schedule

The Zero/Span Schedule is used to program the instrument to perform fully automated zero and span checks or adjustments.

Home Screen>Calibration>Zero/Span Schedule

Home Screen>Calibration>Zero/Span Schedule>More



The Zero/Span Schedule contains the following information:

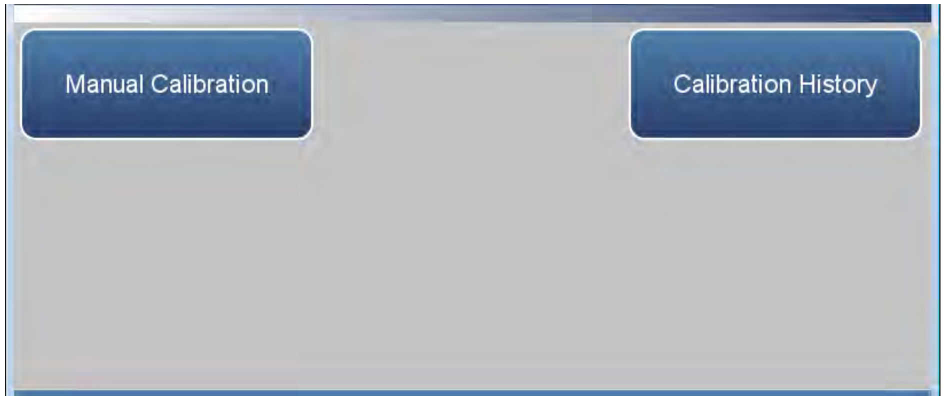
- *Zero/Span Schedule:* Toggles zero/span schedule Enabled or Disabled.
- *Next Time:* Allows the user to view and set the initial date and time (24-hour format) of the zero/span schedule.
- *Period:* Defines the period or interval between zero/span checks or calibrations. If period = 0, the schedule runs continuously.
- *Zero Duration:* Sets how long zero air is sampled by the instrument.
- *Span Duration:* Sets how long span gas is sampled by the instrument.
- *Purge Duration:* Sets how long the purge period will be at the end of the schedule.

- *Total Duration:* Read only. Displays the total time duration of all scheduled events.
- *Schedule Averaging Time:* Allows the user to adjust the zero/span schedule averaging time. This averaging time only affects the zero/span schedule.
- *Background Calibration:* Toggles Enabled/Disabled. If enabled, background value is calibrated. If disabled, schedule runs a background check only and background value is not updated.
- *Span Calibration:* Toggles Enabled/Disabled. If enabled, span coefficient is calibrated. If disabled, schedule runs a calibration check only and span coefficient is not updated.
- *Zero : Span Ratio:* Allows the user to perform more scheduled background calibration checks to span calibration checks. Default is 1 and therefore reads 1:1. (This means that each time the schedule is run, both the zero duration and span duration occurs.) The zero/span ratio is allowable between 1 to 99. If 99 is chosen, the schedule should only perform the Span on the 99th iteration.

Advanced Calibration

The Advanced Calibration screen provides a manual way to calibrate the instrument and view the calibration history. See Chapter 4 “Calibration” for further instructions on how to run a calibration.

Home Screen>Calibration>Advanced Calibration



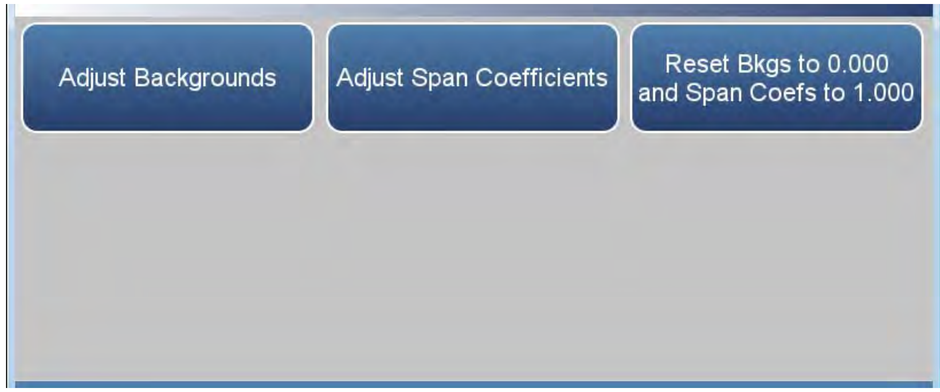
The Advanced screen contains the following information:

- *Manual Calibration:* The user manually adjusts the background or span coefficient.
- *Calibration History:* Lists all calibrations performed and calibration checks.

Manual Calibration

The Manual Calibration screen adjusts the zero background or span coefficient based on a user entered value. See Chapter 4, "Calibration" for instructions on how to run a Manual Calibration.

Home Screen>Calibration>Advanced Calibration>Manual Calibration



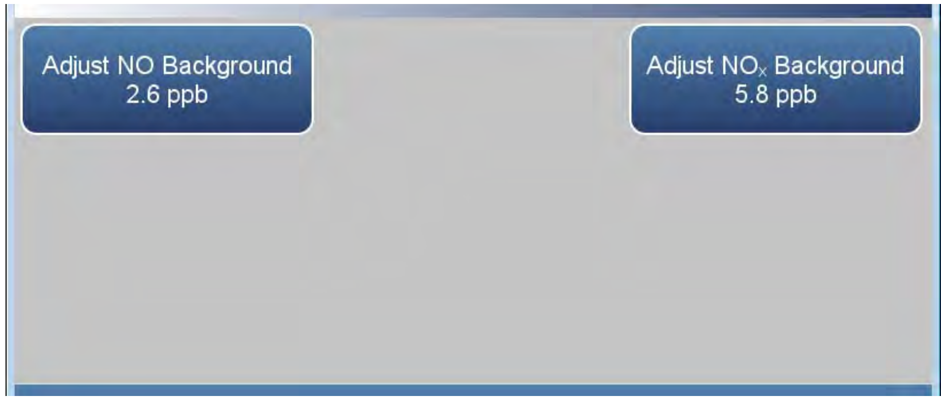
The Manual Calibration screen contains the following information:

- *Adjust Backgrounds:* Allows the user to manually adjust the zero backgrounds.
- *Adjust Span Coefficients:* Allows the user to manually adjust the span coefficients.
- *Reset Bkgs to 0.000 and Span Coef to 1.000:* Resets all backgrounds and coefficients.

Adjust Backgrounds

The Adjust Backgrounds screens are used to manually adjust the NO and NO_x zero background.

Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Backgrounds



The Adjust Backgrounds screen contains the following information:

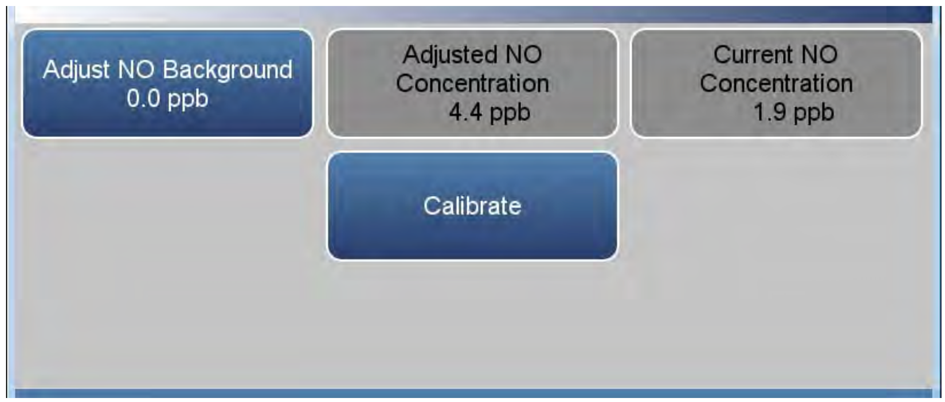
- *Adjust NO Background:* User manually adjusts zero NO background.
- *Adjust NO_x Background:* User manually adjusts zero NO_x background.

Adjust NO and NO_x Background

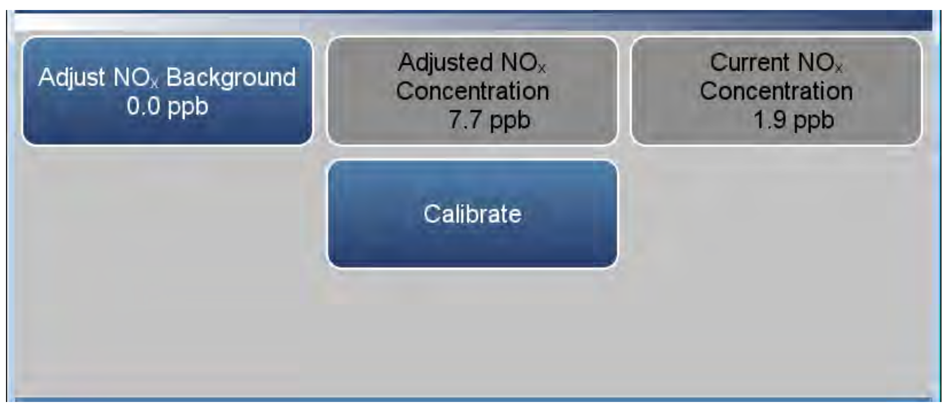
The Adjust NO and NO_x Background screens are used to adjust the instrument zero background. Before making an adjustment, be sure the analyzer samples zero air for at least 5 minutes.

It is important to note the averaging time when calibrating. The longer the averaging time the more precise the calibration results. To achieve maximum precision, allow the instrument to stabilize each time input gas is changed and set the averaging time to 300-second averaging.

Home Screen>Calibration> Advanced Calibration>Manual Calibration>Adjust Backgrounds>Adjust NO Background



Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Backgrounds>Adjust NO_x Background



The Adjust NO and NO_x Background screens contains the following information:

- *Adjust NO Background:* User manually adjusts zero NO background.
- *Adjusted NO Concentration:* Read only. Displays what the NO concentration value will become when the calibrate button is pressed.

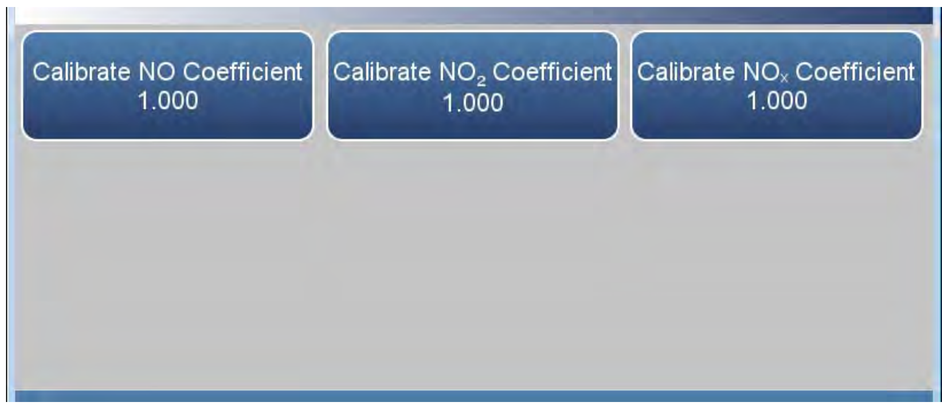
- *Current NO Concentration:* Read only. Displays the current NO concentration.
- *Adjust NO_x Background:* User manually adjusts zero NO_x background.
- *Adjusted NO_x Concentration:* Read only. Displays what the NO_x concentration value will become when the calibrate button is pressed.
- *Current NO_x Concentration:* Read only. Displays the current NO_x concentration.
- *Calibrate:* When pressed, updates the background.

Adjust Span Coefficients

The Adjust Span Coefficients screens are used to manually adjust the span coefficients.

The following screen is shown in single range mode and dual or auto range mode. In dual or auto range modes, "High Range" or "Low Range" buttons are displayed to indicate the calibration of the high or low coefficient. The Adjust High Span Coefficient and Adjust Low Span Coefficient screens function the same way as the (single range) Adjust Span Coefficient screen.

Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Span Coefficients (single range mode)



Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Span Coefficients (dual range mode)

The Adjust Span Coefficients screen contains the following information:

- *Calibrate NO Coefficient:* Adjusts the NO coefficient when in single range mode.
- *Calibrate NO High Range Coefficient:* Adjusts the NO high range coefficient when in dual or auto range mode.

- *Calibrate NO Low Range Coefficient:* Adjusts the NO low range coefficient when in dual or auto range mode.
- *Calibrate NO_2 Coefficient:* Adjusts the NO_2 coefficient when in single range mode.
- *Calibrate NO_2 High Range Coefficient:* Adjusts the NO_2 high range coefficient when in dual or auto range mode.
- *Calibrate NO_2 Low Range Coefficient:* Adjusts the NO_2 low range coefficient when in dual or auto range mode.
- *Calibrate NO_x Coefficient:* Adjusts the NO_x coefficient when in single range mode.
- *Calibrate NO_x High Range Coefficient:* Adjusts the NO_x high range coefficient when in dual or auto range mode.
- *Calibrate NO_x Low Range Coefficient:* Adjusts the NO_x low range coefficient when in dual or auto range mode.

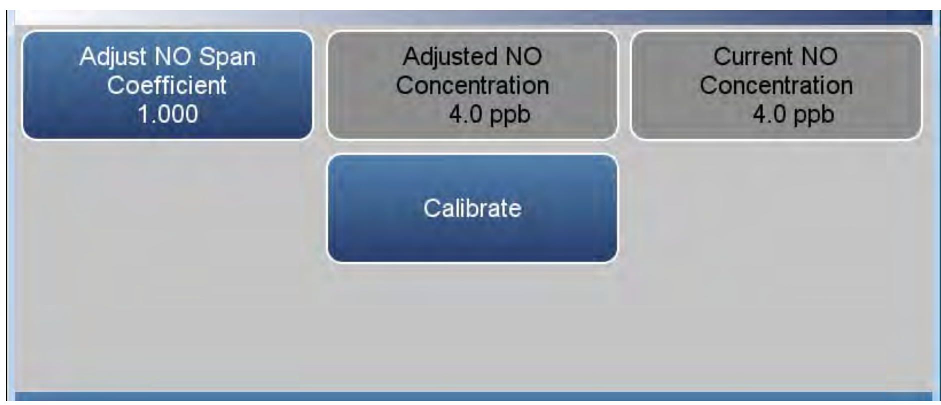
Adjust NO, NO_2, and NO_x Span Coefficients

The Adjust NO, NO_2, and NO_x Span Coefficient screens are used to manually adjust the coefficient and enter the span concentration. The NO span coefficient is calculated, stored, and used to correct the current reading. All calibration screens function the same way. Therefore, the following example of the NO screen applies to the NO_2 and NO_x calibration screens as well.

The following screen is shown in single range mode and dual or auto range mode. In dual or auto range modes, “High Range” or “Low Range” is displayed to indicate the calibration of the high or low coefficient. The Adjust High Range NO Span Coefficient and Adjust Low Range NO Span Coefficient screens function the same way.

It is important to note the averaging time when calibrating. The longer the averaging time the more precise the calibration results. To achieve maximum precision, allow the instrument to stabilize each time input gas is changed and set the averaging time to 300-second averaging.

Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Span Coefficients>Adjust NO Span Coefficient (single range mode)



Home Screen> Calibration>Advanced Calibration>Manual Calibration>Adjust Coefficients> Adjust High Range NO Span Coefficient (dual or auto range mode)

The Adjust NO Span Coefficient screens contain the following information:

- *Adjust NO Span Coefficient:* User manually adjusts NO span coefficient when in single range mode.
- *Adjusted NO Concentration:* Read only. Shows adjusted NO concentration based on adjusted NO span coefficient when in single range mode.
- *Current NO Concentration:* Read only. Shows current NO concentration when in single range mode.
- *Adjust High Range NO Span Coefficient:* User manually adjusts the high range NO span coefficient when in dual or auto range mode.
- *Adjusted High Range NO Concentration:* Read only. Shows adjusted high range NO concentration based on adjusted high range NO span coefficient when in dual or auto range mode.
- *Current High Range NO Concentration:* Read only. Shows current high range NO concentration when in dual or auto range mode.
- *Adjust Low Range NO Span Coefficient:* User manually adjusts the NO low span coefficient when in dual or auto range mode.
- *Adjusted Low Range NO Concentration:* Read only. Shows adjusted NO concentration based on adjusted low range NO span coefficient when in dual or auto range mode.
- *Adjusted Low Range NO Concentration:* Read only. Shows current low range NO concentration when in dual or auto range mode.
- *Calibrate:* Calibrates span coefficient by saving the newly adjusted span coefficient.

Calibration History

The Calibration History screen shows the log of calibrations and calibration checks performed.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Calibration>Advanced Calibration>Calibration History

Note Pressing the Calibration History button responds with Retrieving calibration log data, it may take a few seconds... ▲

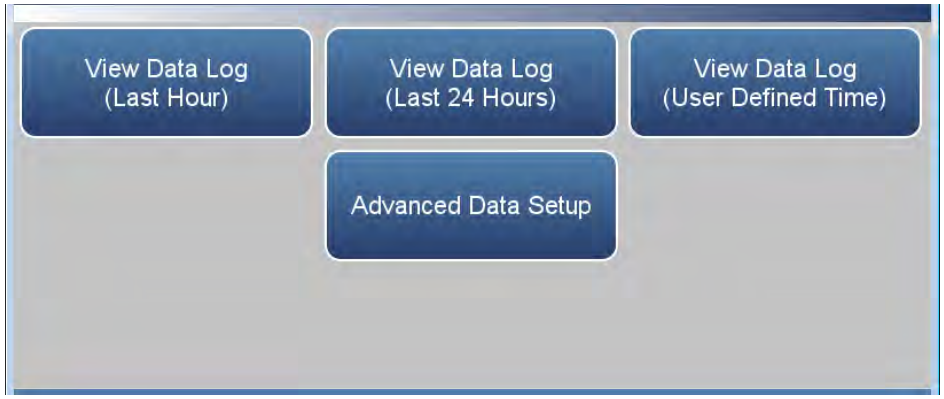
The Calibration History screen contains the following information:

- *Time Stamp:* Time of calibration or calibration check.
- *Event:* Lists the type of calibration event.
- *Result:* Concentration result.
- *Target:* Concentration setpoint value.
- *Units:* Displays units for each item.
- *Average Time:* Averaging time used during the calibration or calibration check.

Data

The Data screen is used to view and record concentrations and instrument data. Users can view both tabular data and graphed data.

Home Screen>Data



The Data screen contains the following information:

- *View Data Log (Last Hour):* User views last hour of historical data. Table shows most recent data on top.
- *View Data Log (Last 24 Hours):* User views 24-hour of historical data. Table shows most recent data on top.
- *View Data Log (User Defined Time):* User selects the start and end time for viewing the data. Table shows most recent data on top.
- *Advanced Data Setup:* Allows the user to set up the parameters of how the data is stored.

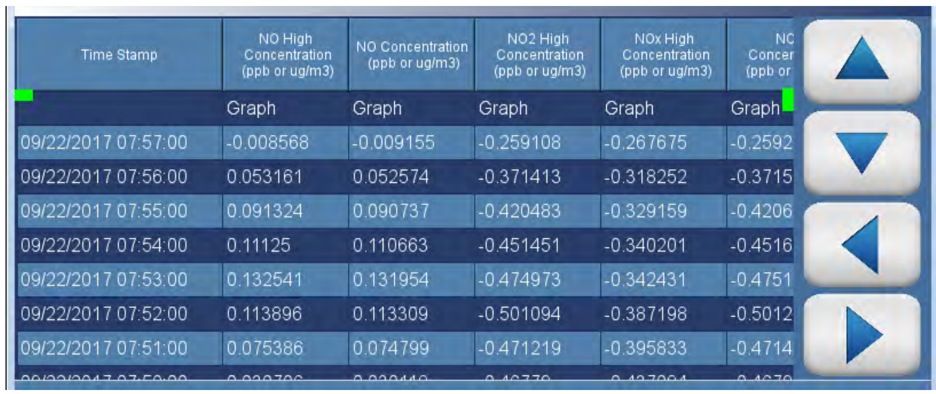
View Data Log (Last Hour)

The View Data Log (Last Hour) screen allows the user to instantly view the last hour worth of data in real time.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

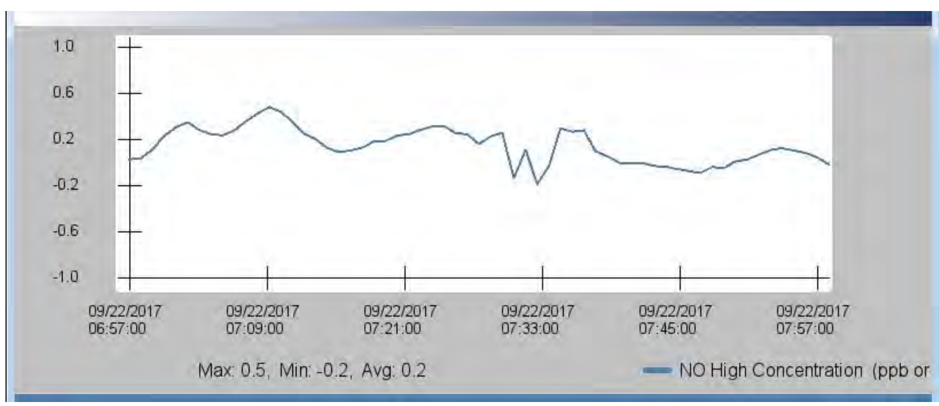
Home Screen>Data>View Data Log (Last Hour)

Note Pressing the View Data Log (Last Hour) responds with Retrieving user log data, it may take a few seconds... ▲



The View Data Log (Last Hour) screen contains the following options:

- *Graph:* Displays data graph for the column selected. The graph time axis is defined by the data set in the table.



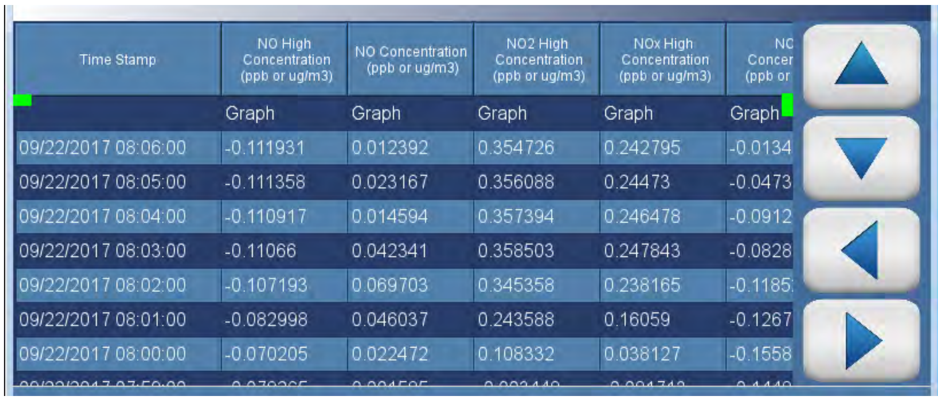
View Data Log (Last 24 Hours)

The View Data Log (Last 24 Hours) screen allows the user to instantly view the last 24 hours worth of data in real time.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

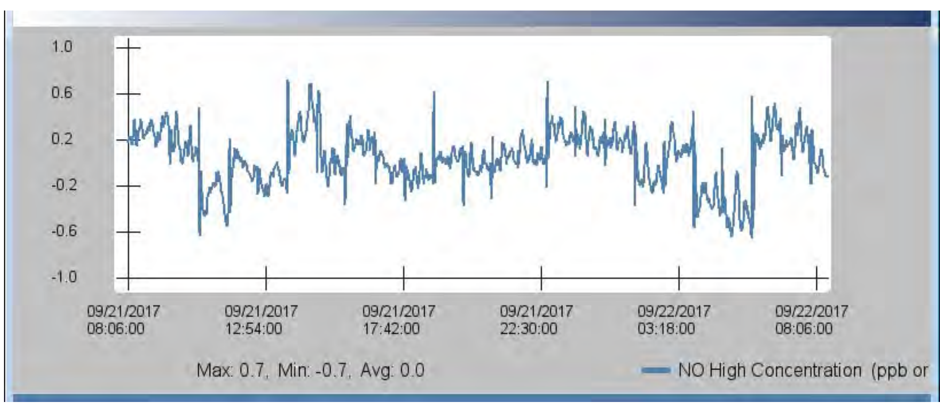
Home Screen>Data>View Data Log (Last 24 Hours)

Note Pressing the View Data Log (Last 24 Hours) responds with Retrieving user log data, it may take a few seconds... ▲



The View Data Log (Last 24 Hours) screen contains the following options:

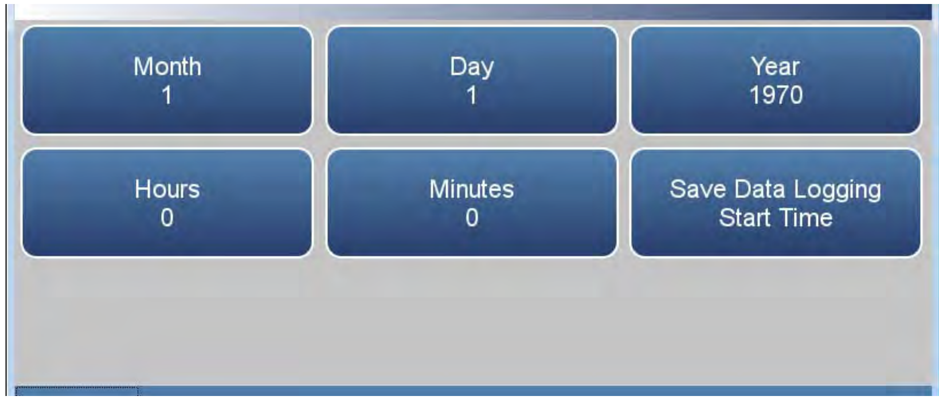
- *Graph:* Displays data graph for the column selected. The graph time axis is defined by the data set in the table.



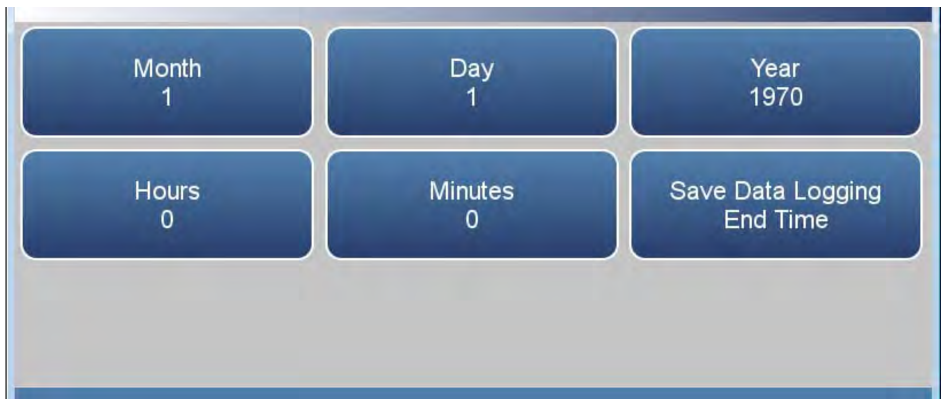
View Data Log (User Defined Time)

The View Data (User Defined Time) screen is used to specify the start and end time for viewing the data logging table.

Home Screen>Data>View Data Log (User Defined Time)



Home Screen>Data>View Data Log (User Defined Time)>Save Data Logging Start Time



The View Data Log (User Defined Time) screen contains the following information:

- *Month:* Sets month of data logging start time.
- *Day:* Sets day of data logging start time.
- *Year:* Sets year of data logging start time.
- *Hours:* Sets hours of data logging start time.
- *Minutes:* Sets minutes of data logging start time.
- *Save Data Logging Start Time:* Pressing this button saves the start time and follows directly to the end time selection for the data logging screen.

The View Data Log (User Defined Time) End Time screen contains the following information:

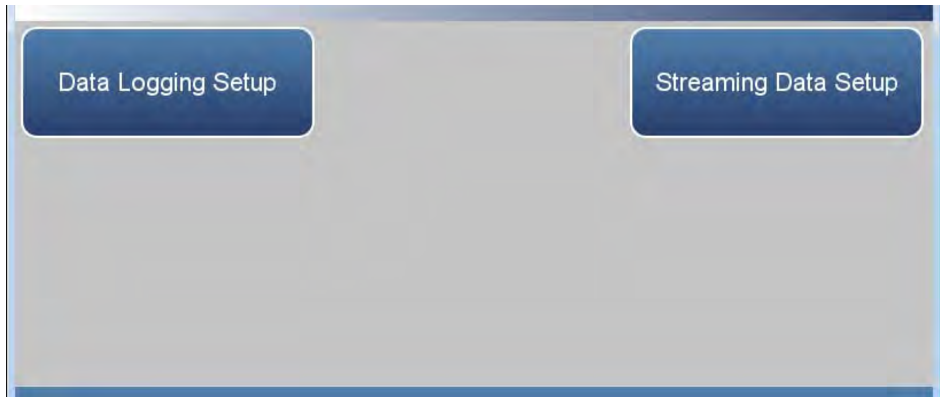
- *Month:* Sets month of data logging end time.
- *Day:* Sets day of data logging end time.
- *Year:* Sets year of data logging end time.
- *Hours:* Sets hour of data logging end time.
- *Minutes:* Sets minute of data logging end time.
- *Save Data Logging End Time:* Pressing the Save Data Logging End Time button saves the end time and follows directly to the data logging table.

Note End time should not be greater than 1 year from start time . ▲

Advanced Data Setup

The Advanced Data Setup screen allows the user to select variables and set up parameters for data logging and streaming data.

Home Screen>Data>Advanced Data Setup



The Advanced Data Setup screen contains the following information:

- *Data Logging Setup:* User selects the parameters for collecting logged data.
- *Streaming Data Setup:* User selects the parameters for streaming data to a computer in real time.

Data Logging Setup

The Data Logging Setup screen allows the user to select data to be stored and how it is stored.

Home Screen>Data>Advanced>Data Logging Setup

The Data Logging Setup screen contains the following information:

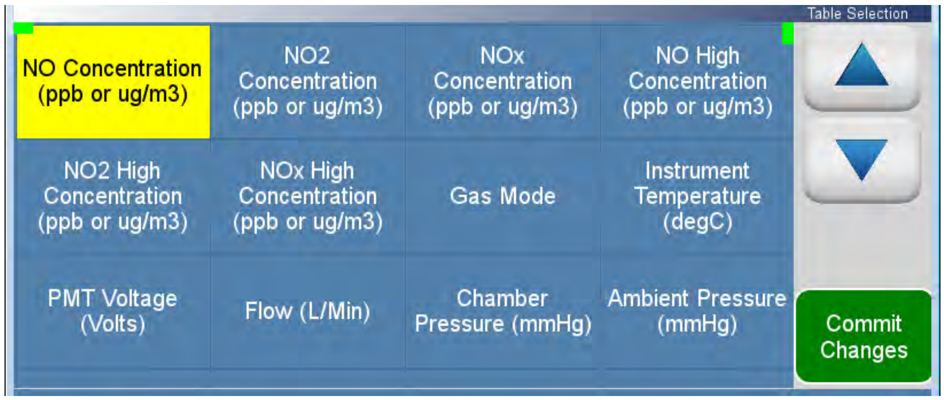
- *Select Data Logging Variables*: User selects instrument variables to log. See "Table 3–1" for data logging variable list.
- *Period*: User selects how often data is collected by setting the duration between logged data.
- *Data Treatment*: Toggles between Average, Current, Minimum and Maximum. When set to average, the average value during the period will be recorded. When set to current, the latest data will be recorded. When set to minimum or maximum, the minimum or maximum value during the period will be recorded.
- *Erase Data Log Records*: Allows the user to erase all values in the data log and updates the data logging table.

Select Data Logging Variables

The Select Data Logging Variables screen allows the user to select which variables to store. Note: The Data logging and Streaming variable lists are **exclusive** from each other but contain the same variable selections.

Use the ▲ and ▼ buttons to scroll through the variables. Select the variables to log by pressing the corresponding cells. Next, press the **Commit Changes** button to save selections. Yellow buttons indicate that the variable is selected.

Home Screen>Data>Advanced>Data Logging Setup>Select Data Logging Variables



The following table contains the variables that can be selected for data logging:

Table 3–1. Data Logging Variables

Description
NO Concentration (ppb or µg/m3)
NO2 Concentration (ppb or µg/m3)
NOx Concentration (ppb or µg/m3)
NO High Concentration (ppb or µg/m3)
NO2 High Concentration (ppb or µg/m3)
NOx High Concentration (ppb or µg/m3)
Gas Mode
Instrument Temperature (degC)
PMT Voltage (Volts)
Flow (L/Min)
Chamber Pressure (mmHg)
Ambient Pressure (mmHg)

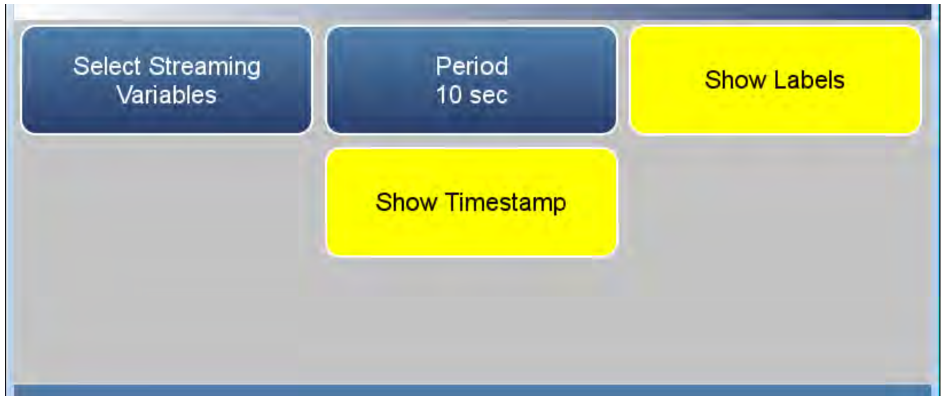
NO Concentration Alarm
NO2 Concentration Alarm
NOx Concentration Alarm
Pressure Alarm
Flow Alarm
Temperature Alarm
Auto Zero Alarm
Auto Span Alarm
Flow Pressure Module Alarms
Concentration Alarms
NO Background (ppb or µg/m3)
NOx Background (ppb or µg/m3)
NO Coefficient
NO2 Coefficient
NOx Coefficient
NO High Coefficient
NO2 High Coefficient
NOx High Coefficient
General Alarm
Alerts
Instrument Error
Low Dynamic Filter Status
High Dynamic Filter Status
Dilution Ratio
PMT42 Alarms
Cooler Temp Alarm
Chamber Temperature Alarm
PMT42 cooler current (Amps)
PMT42 Bench Temperature (degC)
PMT42 Cooler Temperature (degC)
PMT High Voltage (Volts)
Cooler Voltage (Volts)
Converter Temperature Alarm
NO2 Converter Alarms

Converter Temperature (degC)
Heater Duty Cycle (Percent)
Ozonator Alarms
PSB Alarms
Perm Oven Body Temp (deg C)
Perm Oven Gas Temp (deg C)

Streaming Data Setup

The Streaming Data Setup screen allows the user to stream data to a computer.

Home Screen>Data>Advanced>Streaming Data Setup



The Streaming Data Setup screen contains the following information:

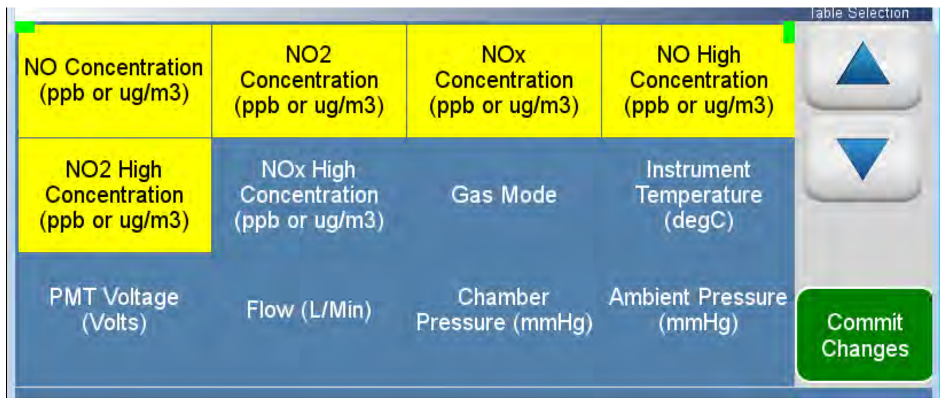
- *Select Streaming Variables*: User selects which variables to stream. See Table 3–2 for streaming variable list.
- *Period*: Sets the time between streamed data.
- *Show Labels*: Toggles on/off. When on, shows variable labels to the left of the variable values.
- *Show Timestamp*: Toggles on/off. When on, shows timestamp at the beginning of each row of data.

Select Streaming Variables

The Select Streaming Variables screen allows the user to select which variables to track. Note: The Data logging and Streaming variable lists are **exclusive** from each other but contain the same variable selections.

Use the ▲ and ▼ buttons to scroll through the variables. Select the variables to log by pressing the corresponding cells. Next, press the **Commit Changes** button to save selections. Yellow buttons indicate that the variable is selected.

Home Screen>Data>Advanced>Streaming Data Setup>Select Streaming Variables



The following table contains the variables that can be selected for streaming data:

Table 3–2. Streaming Data Variables

Description
NO Concentration (ppb or µg/m3)
NO2 Concentration (ppb or µg/m3)
NOx Concentration (ppb or µg/m3)
NO High Concentration (ppb or µg/m3)
NO2 High Concentration (ppb or µg/m3)
NOx High Concentration (ppb or µg/m3)
Gas Mode
Instrument Temperature (degC)
PMT Voltage (Volts)
Flow (L/Min)
Chamber Pressure (mmHg)

Ambient Pressure (mmHg)
NO Concentration Alarm
NO2 Concentration Alarm
NOx Concentration Alarm
Pressure Alarm
Flow Alarm
Temperature Alarm
Auto Zero Alarm
Auto Span Alarm
Flow Pressure Module Alarms
Concentration Alarms
NO Background (ppb or μg/m3)
NOx Background (ppb or μg/m3)
NO Coefficient
NO2 Coefficient
NOx Coefficient
NO High Coefficient
NO2 High Coefficient
NOx High Coefficient
General Alarm
Alerts
Instrument Error
Low Dynamic Filter Status
High Dynamic Filter Status
Dilution Ratio
PMT42 Alarms
Cooler Temp Alarm
Chamber Temperature Alarm
PMT42 cooler current (Amps)
PMT42 Bench Temperature (degC)
PMT42 Cooler Temperature (degC)
PMT High Voltage (Volts)
Cooler Voltage (Volts)
Converter Temperature Alarm

NO2 Converter Alarms
Converter Temperature (degC)
Heater Duty Cycle (Percent)
Ozonator Alarms
PSB Alarms
Perm Oven Body Temp (deg C)
Perm Oven Gas Temp (deg C)

Settings

The Settings screen allows the user to view the status and alarms, set up user preferences, communicate with outside devices and computers, download files to USB, and sets security protocol.

Home Screen>Settings

The Settings screen contains the following information:

- *Health Check:* View instrument status and alarms, predictive diagnostics, preventive maintenance alerts, maintenance history, email health check report files, and contact Thermo Fisher Scientific technical support.
- *Measurement Settings:* Allows the user to setup user preferences as related to the concentration readings.
- *Communications:* Allows the user to communicate with outside devices.
- *Instrument Setting:* Allows the user to setup alarm setpoints and user preferences.
- *Configuration:* User selects which options to enable.
- *Security Access Levels:* User selects security protocol. User can also change security passwords.
- *USB Drive:* User can update instrument firmware, download data, and change USB password.
- *User Contact Information:* User sets up their contact information.
- *Update Bootloader:* Used to update bootloader when an update to the bootloader is available.

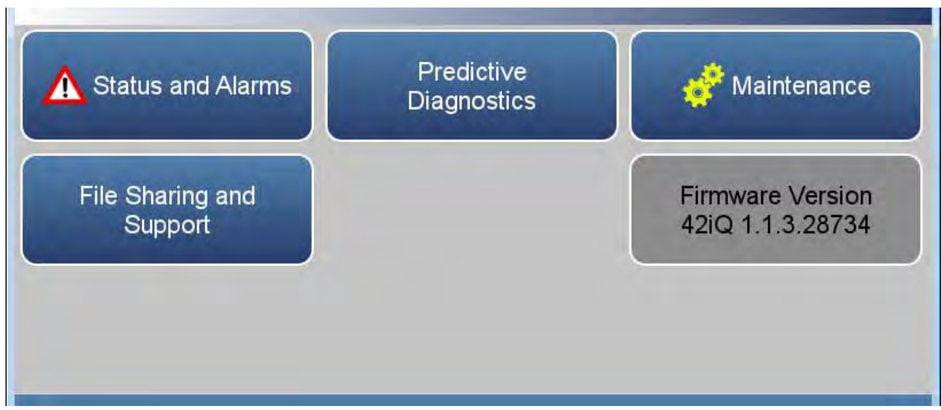
Health Check

The Health Check screen is used for viewing instrument status and alarms, predictive diagnostics, preventive maintenance schedules, maintenance history, emailing files describing the health/status of the instrument, and viewing the instrument's firmware version.

Note This symbol denotes there is an active alarm in the module. ▲

Note This symbol denotes there is an active maintenance alarm in the module. ▲

Home Screen>Settings>Health Check



The Health Check screen contains the following information:

- *Status and Alarms:* Allows the user to view the status and alarm menus. Menus are broken down according to modules where the user can view instrument readings, setpoints and alarms.
- *Predictive Diagnostics:* Smart module diagnostics, which shows possible future issues.
- *Maintenance History:* Allows the user to set up a maintenance schedule and track maintenance history.
- *File Sharing and Support:* File sharing via email. Support through Thermo Fisher Scientific technical support.
- *Firmware Version:* Shows the instrument's firmware version.

Status and Alarms

The Status and Alarms screen provides information with respect to module alarms. In each screen, instrument readings, setpoints, and low/high alarm values are displayed. If applicable, setpoints and alarms are also settable from the Settings>Instrument Settings screen.

Note This symbol denotes there is an active alarm in the module. ▲

Home Screen>Settings>Health Check>Status and Alarms

Home Screen>Settings>Health Check>Status and Alarms>More

The Status and Alarms screen contains the following information:

- *Concentration:* Displays $NO/NO_2/NO_x$ concentrations and alarms.
- *Reaction Chamber:* Displays reaction chamber alarms and faults.
- *Ozonator:* Displays ozonator alarms and faults.
- *NO_2 Converter:* Displays NO_2 converter alarms and faults.
- *Perm Oven:* Displays perm oven module alarms and faults.

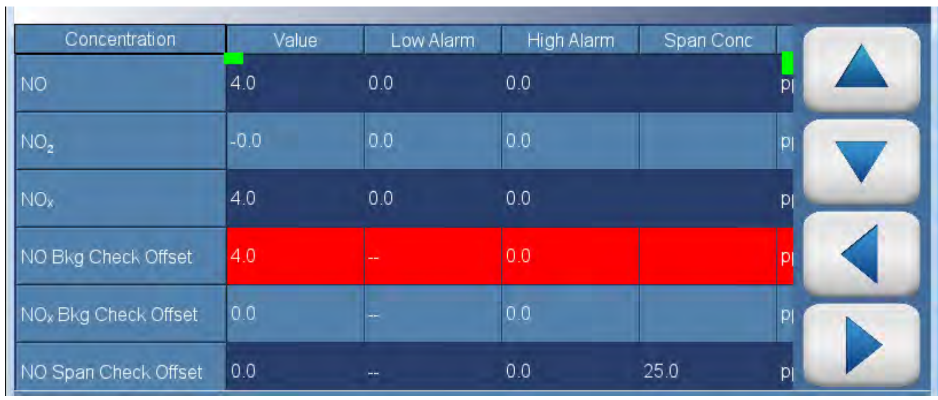
- *Flow and Pressure:* Displays flow and pressure alarms and faults.
- *Peripherals Support:* Displays peripherals support alarms and faults.
- *Valve and Pump Resets:* User can reset valve and pump power.
- *Analog I/O:* Displays analog input/output alarms and faults.
- *Digital I/O:* Displays digital input/output alarms and faults.
- *Serial Numbers:* Displays all the serial numbers for the instrument.

Concentration

The Concentration screen provides status and alarms for $NO/NO_2/NO_x$ concentration, background cal/checks, and span cal/checks. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>Concentration



The Concentration screen contains the following information:

- Across:
    - *Concentration:* This column lists items associated with the $NO/NO_2/NO_x$ concentrations.
    - *Value:* Displays the current value for each item.
    - *Low Alarm:* Displays low alarm for each item.
    - *High Alarm:* Displays high alarm for each item.
    - *Span Conc:* Span concentration used in the span calibration or span check.
    - *Units:* Displays units for each item.
- Down:
    - *NO:* NO concentration.
    - *NO_2:* NO_2 concentration.
    - *NO_x:* NO_x concentration.

- *NO Bkg Check Offset:* Displays NO concentration based on the last attempted background calibration. High alarm shows user defined limit for acceptable background check offset.
- *NO_x Bkg Check Offset:* Displays NO_x concentration based on the last attempted background calibration. High alarm shows user defined limit for acceptable background check offset.
- *NO Span Check Offset:* Displays NO concentration based on the last attempted span calibration. High alarm shows user defined limit for acceptable span check offset (compared to the span concentration value). Span concentration shows span setpoint.
- *NO_x Span Check Offset:* Displays NO_x concentration based on the last attempted span calibration. High alarm shows user defined limit for acceptable span check offset (compared to the span concentration value). Span concentration shows span setpoint.

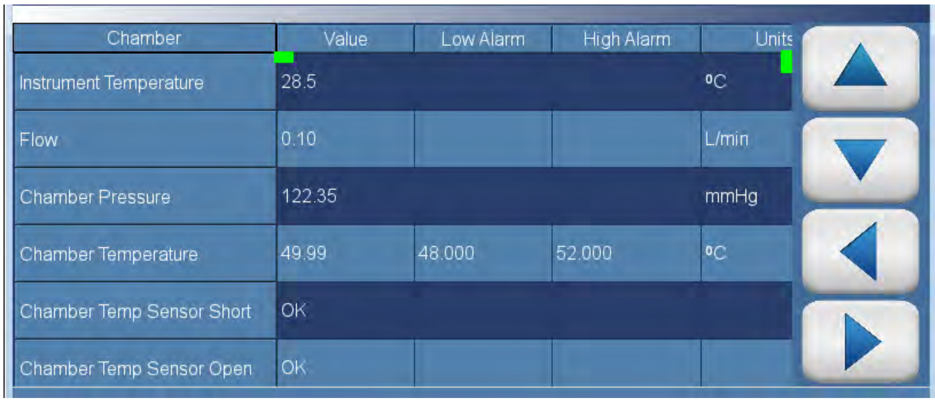
Note If both the low alarm and high alarms are set to zero, then no alarm will show. ▲

Reaction Chamber

The Reaction Chamber screen provides status and alarms related to the reaction chamber module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>Reaction Chamber



The Reaction Chamber screen contains the following information:

- Across:
  - *Chamber:* This column lists items associated with the reaction chamber.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Instrument Temperature:* Displays the current instrument temperature reading.
  - *Flow:* Displays the current sample flow reading.
  - *Chamber Pressure:* Displays the current chamber pressure reading.
  - *Chamber Temperature:* Displays the current chamber temperature reading. User can adjust low and high alarm limits.
  - *Chamber Temp Sensor Short:* Displays OK/Fail for chamber temperature sensor short.

- *Chamber Temp Sensor Open:* Displays OK/Fail for chamber temperature sensor open.
- *Cooler Temperature:* Displays OK/Fail for cooler temperature. User can adjust low and high alarm limits.
- *Cooler Temp Sensor Short:* Displays OK/Fail for cooler temperature sensor short.
- *Cooler Temp Sensor Open:* Displays OK/Fail for cooler temperature sensor open.
- *Cooler Current:* Displays the cooler current reading.
- *Cooler Current too Low:* Displays OK/Fail for cooler current too low.
- *Cooler Current too High:* Displays OK/Fail for cooler current too high.
- *Cooler Voltage:* Displays the current cooler voltage reading.
- *Cooler Voltage too Low:* Displays OK/Fail for cooler voltage too low.
- *Cooler Voltage too High:* Displays OK/Fail for cooler voltage too high.
- *PMT Voltage:* Displays the current PMT voltage reading.
- *PMT Voltage too Low:* Displays OK/Fail for PMT voltage too low.
- *PMT Voltage too High:* Displays OK/Fail for PMT voltage too high.
- *Frequency:* Displays the current frequency reading.
- *Frequency too Low:* Displays OK/Fail for frequency too low.
- *Frequency too High:* Displays OK/Fail for frequency too high.
- *Low Gain:* Displays the current low gain reading.
- *Gain:* Displays the current gain reading.
- *Board Communication:* Displays OK/Fail for board communication status.
- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
  - *3.3 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *5 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

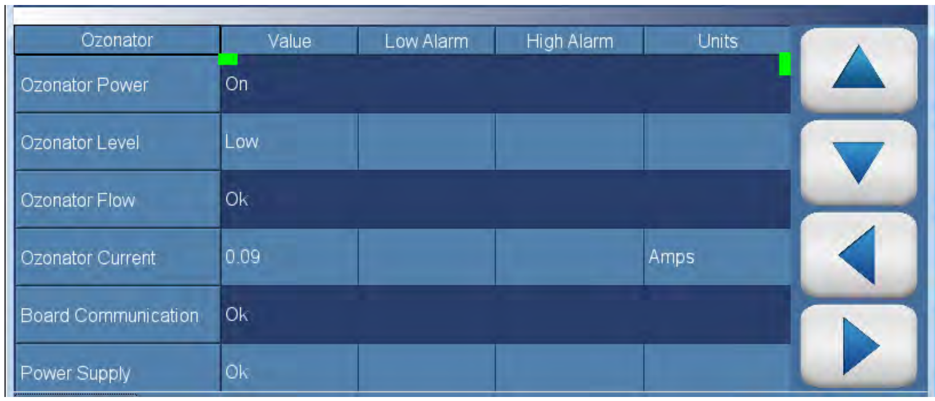
- *12 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *-12 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *24 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

Ozonator

The Ozonator screen provides status and alarms related to the ozonator module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>Ozonator



The Ozonator screen contains the following information:

- Across:
  - *Ozonator:* This column lists items associated with the ozonator.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Ozonator Power:* Displays the current ozonator power on or off.
  - *Ozonator Level:* Displays the current ozonator level.
  - *Ozonator Flow:* Displays OK/Fail for ozonator flow.
  - *Ozonator Current:* Displays the current ozonator Current.
  - *Board Communication:* Displays OK/Fail for board communication status.
  - *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.

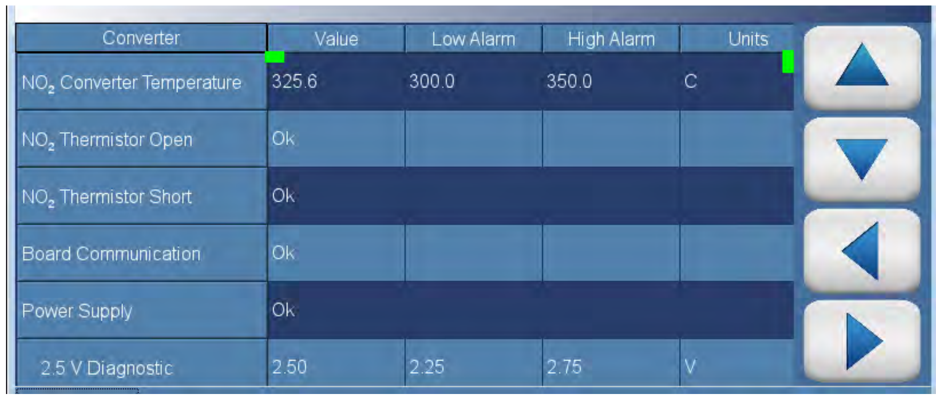
- *3.3 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *5 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *15 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *24 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

NO_2 Converter

The NO_2 Converter screen provides status and alarms related to the NO_2 converter. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>NO_2 Converter



The NO_2 Converter screen contains the following information:

- Across:
  - *Converter:* This column lists items associated with the NO_2 converter.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *NO_2 Converter Temperature:* Displays the current NO_2 converter temperature reading. User can adjust low and high alarm limits.
  - *NO_2 Thermocouple Open:* Displays OK/Fail for NO_2 thermocouple open.
  - *NO_2 Thermocouple Short:* Displays OK/Fail for NO_2 thermocouple short.
  - *Board Communication:* Displays OK/Fail for board communication status.

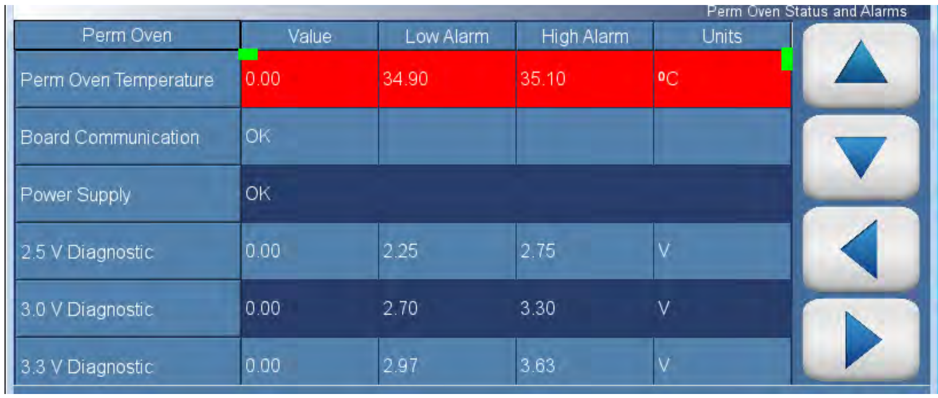
- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
  - *2.5 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *3 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *3.3 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *5 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

Perm Oven

The Perm Oven screen provides status and alarms for the permeation oven, if installed. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>Perm Oven



The Perm Oven screen contains the following information:

- Across:
  - *Perm Oven:* This column lists items associated with the perm oven.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm for each item.
  - *High Alarm:* Displays high alarm for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Perm Oven Temperature:* Displays the current perm oven temperature. User can adjust low and high alarm limits.
  - *Board Communication:* Displays OK/Fail for board communication status.
  - *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
  - *2.5 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

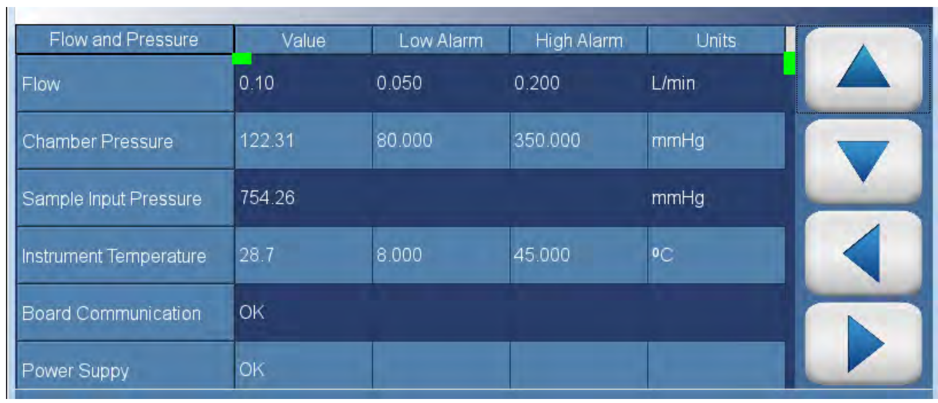
- *3.0 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *3.3 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *5.0 V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *Heater Power Diagnostic:* Displays current heater voltage readings. Alarm limits are not changeable.

Flow and Pressure

The Flow and Pressure screen provides status and alarms related to the flow and pressure module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>Flow and Pressure



The Flow and Pressure screen contains the following information:

- Across:
  - *Flow and Pressure:* This column lists items associated with the flow and pressure module.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Flow:* Displays the current flow reading. User can adjust low and high alarm limits.
  - *Chamber Pressure:* Displays the current chamber pressure reading. User can adjust low and high alarm limits.
  - *Sample Input Pressure:* Displays the current sample input pressure reading.
  - *Instrument Temperature:* Displays the current instrument temperature reading. User can adjust low and high alarm limits.

- *Board Communication:* Displays OK/Fail for board communication status.
- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
    - *2.5V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *3.3V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *5.0V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *24V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

Peripherals Support

The Peripherals Support screen provides status and alarms related to the peripherals module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms> Peripherals Support

The Peripherals Support screen contains the following information:

- Across:
  - *PSB:* This column lists items associated with the peripherals support.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Module Temperature:* Displays the current temperature of the module.
  - *Sample Valve:* Displays whether or not the sample valve is activated.
  - *Zero Valve:* Displays whether or not the zero valve is activated.
  - *Span Valve:* Displays whether or not the span valve is activated.
  - *NO/NOx Mode Valve:* Displays whether or not the NO/NO_x mode valve is activated.

- *Lag Vol Mode Valve:* Displays whether or not the lag volume mode valve is activated.
- *Pump:* Displays the current pump reading.
- *Instrument Error:* Displays OK/Fail for PCP, datalogging, streaming, serial server, and Modbus protocols.
- *Board Communication:* Displays OK/Fail for board communication status.
- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
  - *2.5V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *3.3V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *5.0V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *24V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
- *5.0V Step Board 1:* Displays OK/Fail.
- *24V Step Board 1:* Displays OK/Fail.
- *5.0V Step Board 2:* Displays OK/Fail.
- *24V Step Board 2:* Displays OK/Fail.

Valve and Pump Resets

The Valve and Pump Resets screen allows the user to reset a valve or pump after a failure due to excessive amperage.

Note This symbol denotes that the device needs to be reset. ▲

Note Resetting one valve will reset all valves. ▲

Home Screen>Settings>Health Check>Status and Alarms> Valve and Pump Resets

The Valve and Pump Resets screen contains the following information:

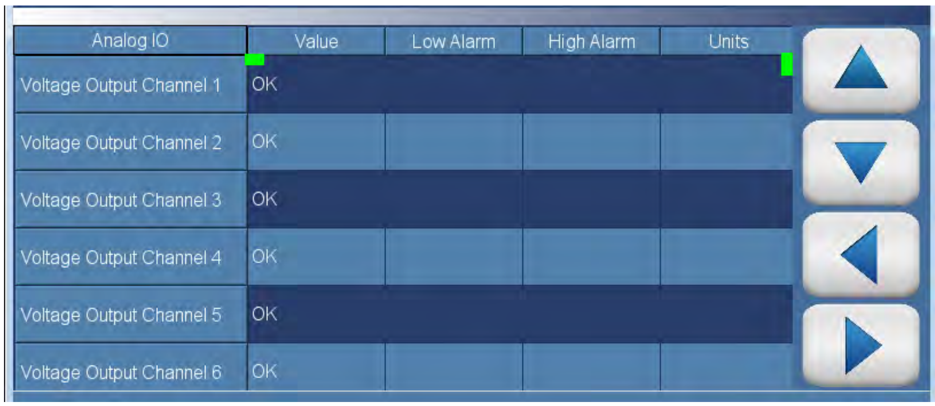
- *Sample Valve Reset:* Resets sample valve.
- *Zero Valve Reset:* Resets zero valve.
- *Span Valve Reset:* Resets span valve.
- *NO/NO$_x$ Valve Reset:* Resets NO/NO$_x$ valve.
- *Pump Reset:* Resets pump.

Analog I/O

The Analog I/O screen provides status and alarms related to the analog input/output module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>More>Analog I/O



The Analog I/O screen contains the following information:

- Across:
  - *Analog IO:* This column lists items associated with the analog I/O.
  - *Value:* Displays the current value for each item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Voltage Output Channel 1–6:* Displays real-time voltage output for each channel.
  - *Current Output Channel 1–6:* Displays real-time current output for each channel.
  - *Chip Temperatures:* Displays OK/Fail for chip temperatures.
  - *Chip 1–3 Communication:* Displays OK/Fail for each chip communication.
  - *Test Mode:* Displays test mode on or off.

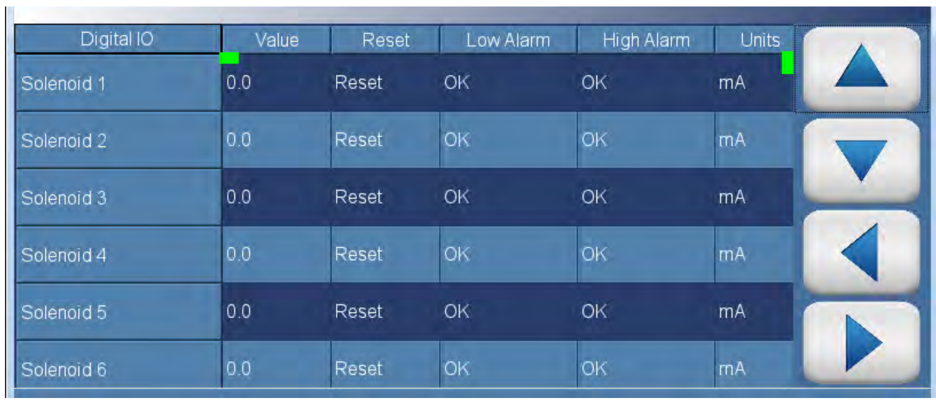
- *Board Communication:* Displays OK/Fail for board communication status.
- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
    - *3.3V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *5.0V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *5.0V Ref Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *15V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
    - *-15V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

Digital I/O

The Digital I/O screen provides status and alarms related to the digital input/output module. If an item being monitored goes outside the lower or higher alarm limit, an alarm is activated.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Status and Alarms>More>Digital I/O



The Digital I/O screen contains the following information:

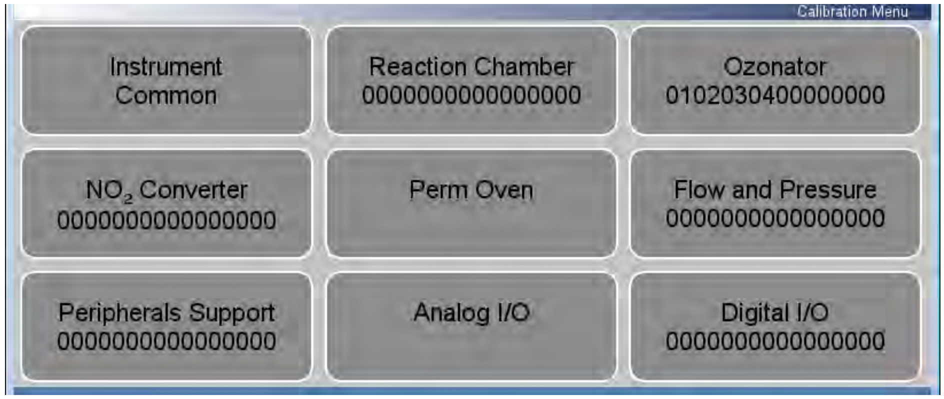
- Across:
  - *Digital IO:* This column lists items associated with the digital I/O.
  - *Value:* Displays the current value for each item.
  - *Reset:* Resets item.
  - *Low Alarm:* Displays low alarm status for each item.
  - *High Alarm:* Displays high alarm status for each item.
  - *Units:* Displays units for each item.
- Down:
  - *Solenoid 1–8:* Displays whether or not the solenoid is activated by showing the current in mA.
  - *External Alarm 1–3:* Displays OK/Fail for external alarms.
  - *Relay Test Mode:* Displays relay test mode on or off.
  - *Solenoid Test Mode:* Displays solenoid test mode on or off.
  - *Board Communication:* Displays OK/Fail for communication status.

- *Power Supply:* Displays OK/Fail of power supplies. Power supply goes red if any voltages are outside their limits. No voltage rows ever get highlighted.
  - *3.3V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *5.0V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.
  - *24V Diagnostic:* Displays current voltage readings. Alarm limits are not changeable.

Serial Numbers

The Serial Numbers screen displays the serial number for each module.

Home Screen>Settings>Health Check>Status and Alarms>More>Serial Numbers



The Serial Numbers screen contains the following information:

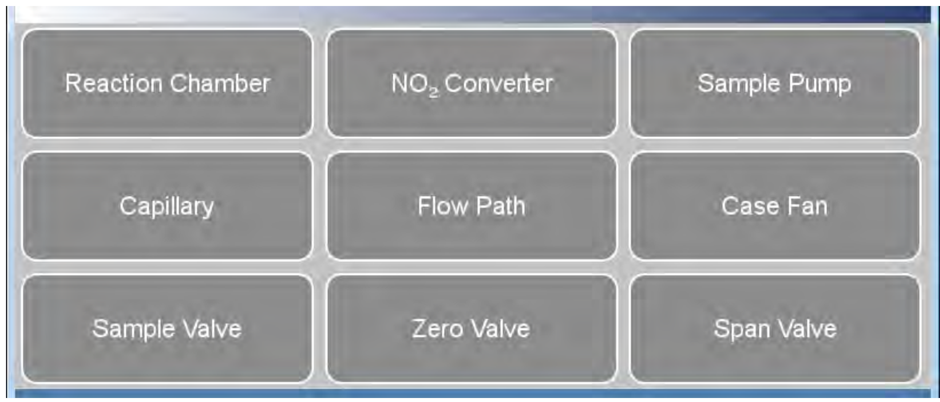
- *Instrument:* Instrument serial number.
- *Reaction Chamber:* Reaction chamber serial number.
- *Ozonator:* Ozonator serial number.
- *NO_2 Converter:* NO_2 converter serial number.
- *Perm Oven:* Optional perm oven serial number.
- *Flow and Pressure:* Flow and pressure serial number.
- *Peripherals Support:* Peripherals support serial number.
- *Analog I/O:* Analog I/O serial number.
- *Digital I/O:* Digital I/O serial number.

Predictive Diagnostics

The Predictive Diagnostics screen is a feature for instruments to anticipate maintenance needs, reduce downtime, and reduce troubleshooting time. If button is greyed out, no maintenance is needed. If button is blue, maintenance is suggested.

Note This symbol denotes there is an active maintenance related warning in the module. ▲

Home Screen>Settings>Health Check>Predictive Diagnostics



The Predictive Diagnostics screen contains the following information:

- Reaction Chamber
- NO_2 Converter
- Sample Pump
- Capillary
- Flow Path
- Case Fan
- Sample Valve
- Zero Valve
- Span Valve

Maintenance

The Maintenance screen reminds the user when certain instrument components need to be serviced/replaced.

Note This symbol denotes there is an active maintenance alarm in the module. ▲

Home Screen>Settings>Health Check>Maintenance

The Maintenance screen contains the following information:

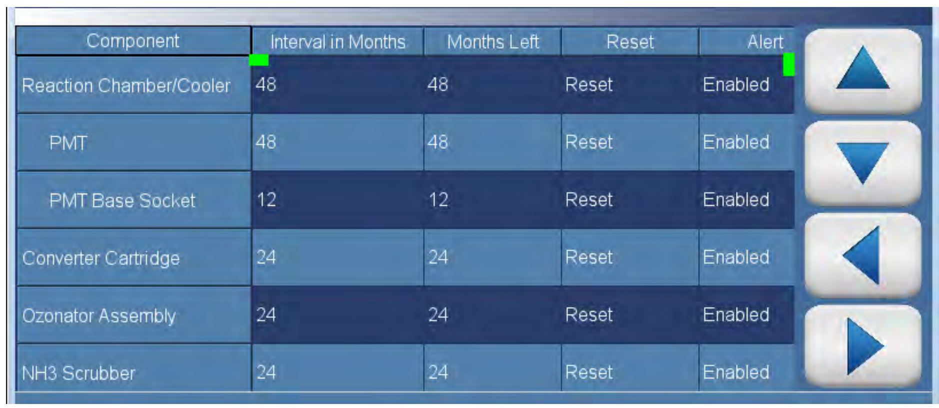
- *Preventive Maintenance:* Shows suggested service interval and time left for component replacement.
- *Change Part:* User logs component fix.
- *Maintenance History:* Shows the log of all recorded component fixes.
- *Advanced Maintenance:* Resets all preventive maintenance items.

Preventive Maintenance

The Preventive Maintenance screen reminds the user when certain instrument components need to be serviced/replaced. When the "Months Left" has decreased to 1, the row is highlighted yellow. If the "Months Left" is 0 or less, the row is highlighted red and the maintenance icon (gears) will appear in the status bar located at the bottom of the screen.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Maintenance>Preventive Maintenance



The Preventive Maintenance screen contains the following information:

- Across:
  - *Component:* Device to be routinely serviced or replaced.
  - *Interval in Months:* Expected period of time before a component needs to be checked and/or serviced.
  - *Months Left:* Count down timer in months. Remaining time since the beginning of the service interval. When the value is 1 or less, the row will be highlighted and it is suggested that the component should be checked and/or serviced.
  - *Reset:* Once the component is serviced/replaced, the user presses the Reset button and the "Months Left" value resets to the "Interval in Months" value.
  - *Alert:* Allows the user to opt out of receiving preventive maintenance alerts. Displays Enabled/Disabled for each component.

- Down:
  - *Reaction Chamber/Cooler:* Consists of the PMT and PMT base socket. Each highlights on their own.
    - *PMT:* Service interval for PMT.
    - *PMT Base Socket:* Service interval for PMT base socket.
  - *Converter Cartridge:* Service interval for converter cartridge.
  - *Ozonator Assembly:* Service interval for ozonator assembly.
  - *NH3 Scrubber:* Service interval for NH3 scrubber.
  - *Permeation Dryer:* Service interval for permeation dryer.
  - *Permeation Tube:* Service interval for the permeation tube.
  - *Flow System:* Service interval for the flow system components.
    - *Pump:* Service interval for pump.
    - *Capillary (Sample):* Service interval for capillaries.
    - *Capillary (Ozone):* Service interval for capillaries.
  - *DC Power Supply:* Service interval for DC power supply.
  - *Fan Filter:* Service interval for fan filter.
  - *System Components:* Service interval for system components.
    - *Purafil:* Service interval for purafil.
    - *Charcoal:* Service interval for charcoal.
    - *Dri-Rite:* Service interval for dri-rite.

Change Part

The Change Part screen allows the user to enter the component being serviced and the type of fix. Pressing commit will update the preventive maintenance table and predictive diagnostics screen when applicable.

Home Screen>Settings>Health Check>Maintenance>Change Part

The Change Part screen contains the following information:

- *Select Part:* User selects part to service from the selection table.
- *Fix:* User chooses from new, rebuilt, cleaned, and unknown.
- *Comment:* User can write a brief comment, which will be saved to the preventive maintenance history table.
- *Commit:* User commits and saves the selected part fix.

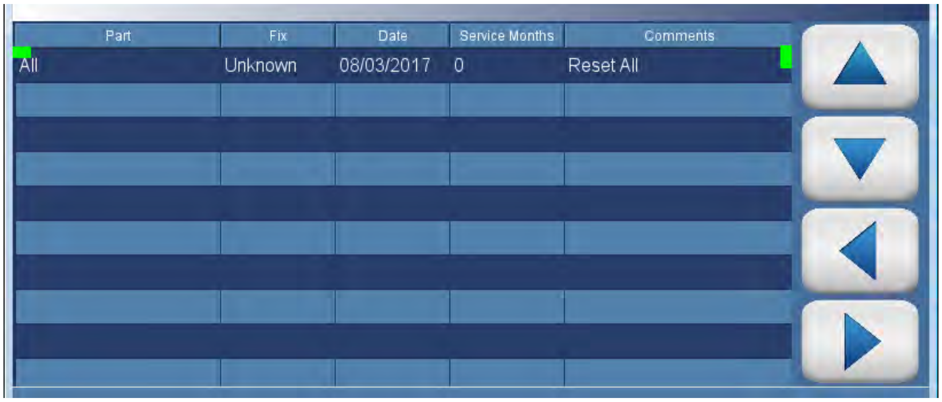
Maintenance History

The Maintenance History screen allows the user to view when components are replaced, rebuilt, or cleaned. When a user changes a part in the change part screen, the new row will be automatically created at the top in the maintenance history table.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Health Check>Maintenance>Maintenance History

Note Retrieving maintenance history data, it may take a few seconds... ▲



The Maintenance History screen contains the following information:

- *Part:* Component that has been fixed.
- *Fix:* The type of maintenance.
- *Date:* Shows date/time when service was logged.
- *Service Months:* Amount of time in months since last service.
- *Comments:* Shows comments entered from time of change.

Advanced Maintenance

The Advanced Maintenance screen resets all preventive maintenance items.

Home Screen>Settigs>Health Check>Maintenance>Advanced Maintenance

File Sharing and Support

The File Sharing and Support screen allows the user to send health check report files to Thermo Fisher Scientific technical support or user emails. The Health Report file includes: Status and Alarms, PM Alerts, Activity Log, Service Database, Cal History, and Data Log (last 24 hours).

Home Screen>Settings>Health Check>File Sharing and Support

The File Sharing and Support screen contains the following information:

- *Download Health Check Report to USB Drive:* Sends the health report to USB drive.
- *Email Health Check Report File to Technical Support:* Sends the health report file to technical support and the customer email addresses via email.
- *Email Health Check Report to Personal Account:* Sends the health report file to a personal account via email.
- *iQ360:* The iQ360 feature is a paid subscription enabling or disabling the instrument to send automated emails to technical support when an alarm or alert is triggered.
- *Request a Field Service Visit:* Sends a field service visit to technical support.

Measurement Settings

The Measurement Settings screen contains a number of submenus where instrument parameters and settings can be read and modified.

Home Screen>Settings>Measurement Settings

The Measurement Settings screen contains the following information:

- *Averaging Time:* Sets the averaging time for the NO, NO_2, and NO_x sample measurements.
- *Range Mode Selection:* User can choose between the various range modes: single, dual, or auto. For more information, see "Range Mode Selection" on page 3-80.
- *Range Settings:* Defines the NO, NO_2, and NO_x concentration range for the analog outputs.
- *Gas Mode:* User can manually choose sample, zero or span mode.
- *Gas Units:* Defines how the NO, NO_2, and NO_x concentration readings are expressed.
- *Dilution Ratio:* Serves as a multiplier when dilution gas is utilized.
- *Advanced Measurement Settings:* Advanced settings affecting NO, NO_2, and NO_x readings.

Averaging Time

The Averaging Time screen allows the user to choose dynamic filter or a manually selected (static) averaging time.

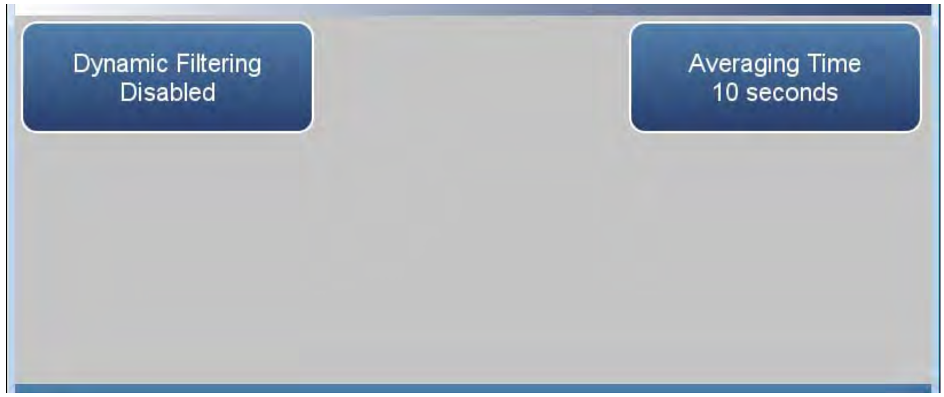
The following screens are shown in single range mode and dual or auto range mode. In the dual and auto range modes, both the “High Range” or “Low Range ” averaging buttons will be available.

Averaging Time defines the time period (1 to 300 seconds) during which NO, NO_2, and NO_x measurements are taken. The average concentration of the readings are calculated for that time period. The front panel display and analog outputs are updated every 10 seconds for averaging times between 10 and 300 seconds. For averaging times of 1, 2, and 5 seconds, the front panel display and analog outputs are updated every second. An averaging time of 10 seconds, for example, means that the average concentration of the last 10 seconds will be displayed every 10 seconds. An averaging time of 300 seconds means that the moving average concentration of the last 300 seconds will be the output at each update. Therefore, the lower the averaging time the faster the front panel display and analog outputs respond to concentration changes. Longer averaging times are typically used to smooth output data.

Dynamic Filtering allows for data smoothing without compromising response time. Automatically changes the averaging time giving the user faster response times when conditions are rapidly changing; smoother and stable readings, when conditions aren’t changing as rapidly; and as an added bonus, it better processes spikes to minimize their impact on the data. At the same time it will preserve the representative nature of the filtered data to the conditions being sampled.

Note When Dynamic Filtering is selected, the user selected Averaging Time button is disabled. ▲

Home Screen>Settings>Measurement Settings>Averaging Time (single range mode)



Home Screen>Settings>Measurement Settings>Averaging Time (dual or auto range mode)

The Averaging Time screen contains the following information:

- *Dynamic Filtering:* Enables/disables dynamic filtering when in single range mode.
- *High Range Dynamic Filtering:* Enables/disables high range dynamic filtering when in dual or auto range mode.
- *Low Range Dynamic Filtering:* Enables/disables low range dynamic filtering when in dual or auto range mode.
- *Averaging Time:* Sets averaging time period when in single range mode and when dynamic filtering is disabled.
- *High Range Averaging Time:* Sets high averaging time when in dual or auto range mode and when dynamic filtering is disabled.
- *Low Range Averaging Time:* Sets high averaging time when in dual or auto range mode and when dynamic filtering is disabled.

Range Mode Selection

The Range Mode Selection screen is used to switch between the various range modes: Single, Dual, and Auto Range.

Home Screen>Settings>Measurement Settings>Range Mode Selection

The Range Mode Selection screen contains the following information:

- *Single:* In single range mode, there is one range, one averaging time, and one span coefficient.
- *Dual:* In the dual range mode, there are two independent analog outputs. These are labeled simply as the "High Range" and the "Low Range". Each channel has its own analog output range setting, averaging time, and span coefficient.

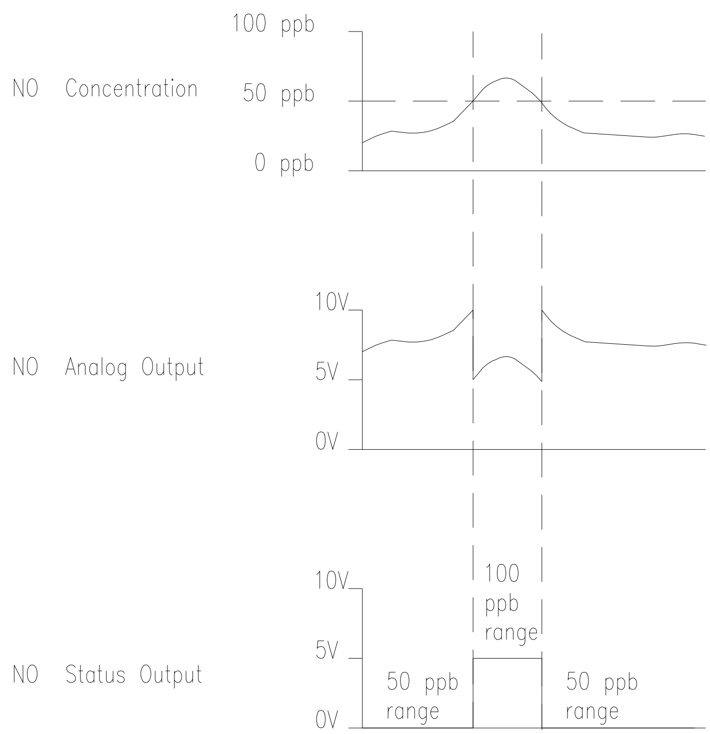
  This enables the sample concentration reading to be sent to the analog outputs at two different ranges. For example, the low NO analog output can be set to output concentrations from 0 to 50 ppb and the high NO analog output set to output concentrations from 0 to 500 ppb.

  In addition to each channel having two ranges, each channel has two span coefficients. There are two span coefficients so that each range can be calibrated separately. This is especially necessary if the two ranges are not close to one another. For example, the low NO range is set to 0–50 ppb and the high NO range is set to 0–20000 ppb.
- *Auto:* The auto range mode switches the NO, NO_2, and NO_x analog outputs between high and low range settings, depending on the concentration level. The high and low ranges are defined in the Range Settings screen.

  For example, suppose the low range is set to 20 ppb and the high range is set to 100 ppb, as shown below. Sample concentrations below 50 ppb are output based on low range selection and sample concentrations above 50 ppb are output based on high range selection. When the low range is active, the range mode selection status output is at 0 volts. When the high range is active, the range mode selection status output is at half of full-scale.

When the high range is active, the NO_x concentration must drop to 95% of the low NO_x range for the low range to become active.

In addition to each channel having two ranges, each channel has two span coefficients. There are two span coefficients so that each range can be calibrated separately. This is especially necessary if the two ranges are not close to one another. For example, the low NO range is set to 0–50 ppb and the high NO range is set to 0–20000 ppb.

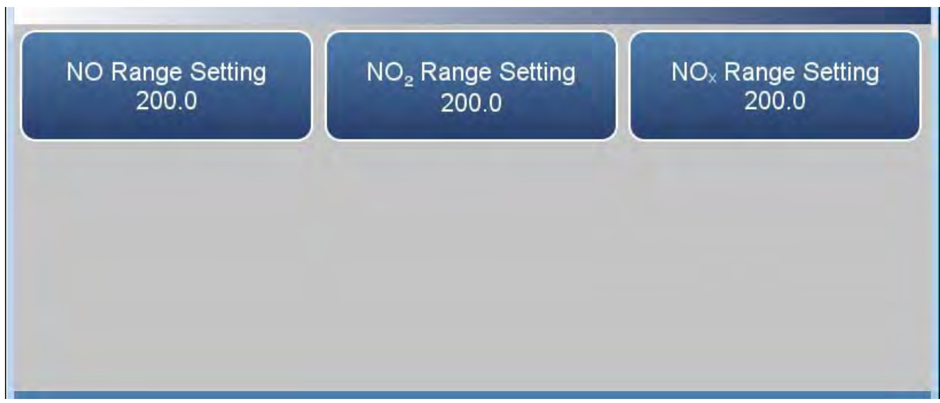


Range Settings

The Range Settings screen defines the concentration range of the analog outputs. For example, an NO_2 range of 0–50 ppb restricts the NO_2 analog output to concentrations between 0 and 50 ppb.

The screen shows the current NO, NO_2, and NO_x range. The range screen is similar for the single, dual, and auto range modes. The only difference between the screens are the words "High" or "Low" displayed to indicate which range is displayed. For more information about the dual and auto range modes, see "Range Mode Selection" on page 3-80. Pressing Range Setting, High Range Setting or Low Range Setting, brings up a numeric keypad whereby the user can select a range.

Home Screen>Settings>Measurement Settings>Range Settings (single range mode)



Home Screen>Settings>Measurement Settings>Range Settings (dual or auto range mode)

The Measurement Settings screen contains the following information:

- *NO Range Setting:* Sets the NO concentration range for the analog outputs when in single range mode.

- *High Range NO Setting:* Sets the high range NO concentration range for the analog output when in dual or auto range mode.
- *Low Range NO Setting:* Sets the low range NO concentration range for the analog output when in dual or auto range mode.
- *NO_2 Range Setting:* Sets the NO_2 concentration range for the analog outputs when in single range mode.
- *High Range NO_2 Setting:* Sets the high range NO_2 concentration range for the analog output when in dual or auto range mode.
- *Low Range NO_2 Setting:* Sets the low range NO_2 concentration range for the analog output when in dual or auto range mode.
- *NO_x Range Setting:* Sets the NO_x concentration range for the analog outputs when in single range mode.
- *High Range NO_x Setting:* Sets the high range NO_x concentration range for the analog output when in dual or auto range mode.
- *Low Range NO_x Setting:* Sets the low range NO_x concentration range for the analog output when in dual or auto range mode.

Settable ranges according to unit selection include:

ppb	50–20000 ppb
ppm	0.05–20 ppm
%	0.000005–0.002 %
µg/m^3	100–30000 µg/m^3
mg/m^3	0.1–30 mg/m^3
g/m^3	.0001–0.030 g/m^3

Gas Mode

The Gas Mode screen defines what gas mode the instrument is set to.

Home Screen>Settings>Measurement Settings>Gas Mode

The Gas Mode screen contains the following information:

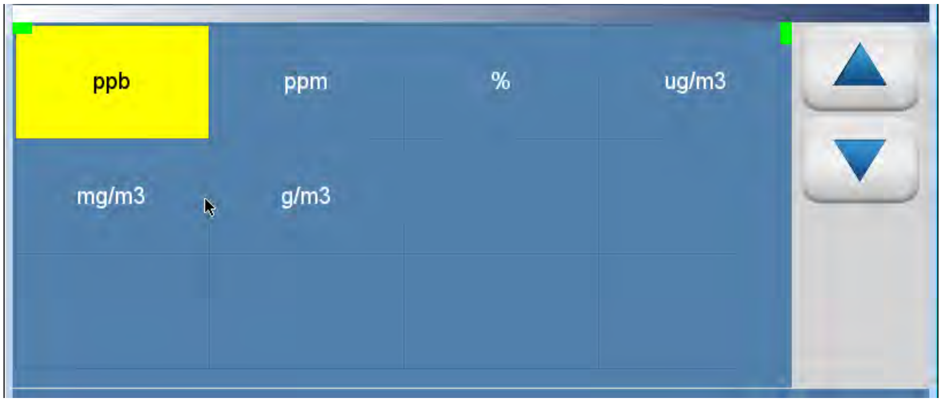
- *Sample:* Sets the instrument to measure sample gas.
- *Zero:* Used when calibrating the background of the instrument. When pressed, sets the instrument to zero mode.
- *Span:* Used when calibrating the span coefficient. When pressed, sets the instrument to span mode.
- *External Span:* If optional perm oven is installed, allows the use of an external span source in addition to the internal permeation span.

Gas Units

The Gas Units screen defines how the NO, NO_2, and NO_x concentration readings are expressed. The µg/m^3, mg/m^3, and g/m^3 gas concentration modes are calculated using a standard pressure of 760 mmHg and a standard temperature of 0 °C.

Use the ▲ and ▼ buttons to move up and down.

Home Screen>Settings>Measurement Settings>Gas Units



The Gas Units screen contains the following information:

- *ppb:* parts per billion.
- *ppm:* parts per million.
- *%:* percent.
- *µg/m3:* micrograms per meter cubed.
- *mg/m3:* milligrams per meter cubed.
- *g/m3:* grams per meter cubed.

Advanced Measurement Settings

The Advanced Measurement Settings screen allows the user to calibrate the reaction chamber and set other advanced settings.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings

The Advanced Measurements Settings screen contains the following information:

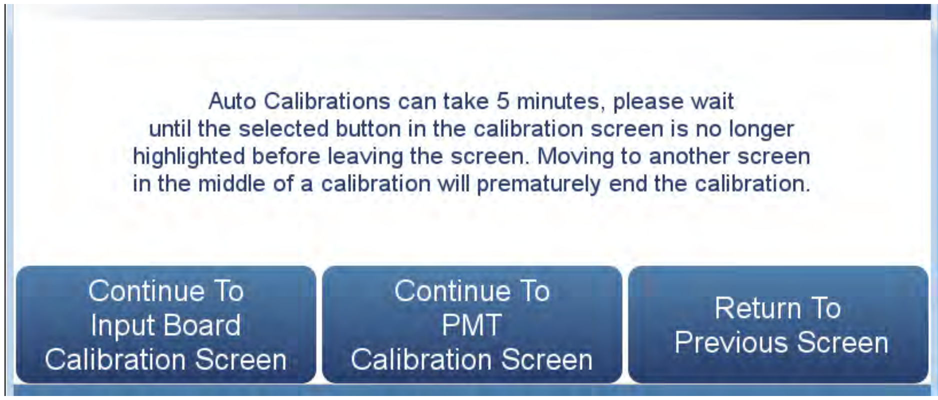
- *Reaction Chamber Settings:* User can calibrate Input board and PMT.
- *Perm Oven Selection:* Allows the user to select the operating temperature of the perm oven.
- *Auto/Manual Mode:* User can choose to measure single gas or switching mode.
- *Extended Ranges:* Enables/disables extended ranges feature.
- *Compensation:* Allows the user to compensate for changes in temperature and pressure concentration.
- *Pressure Calibration:* Calibrates pressure.

Reaction Chamber Settings

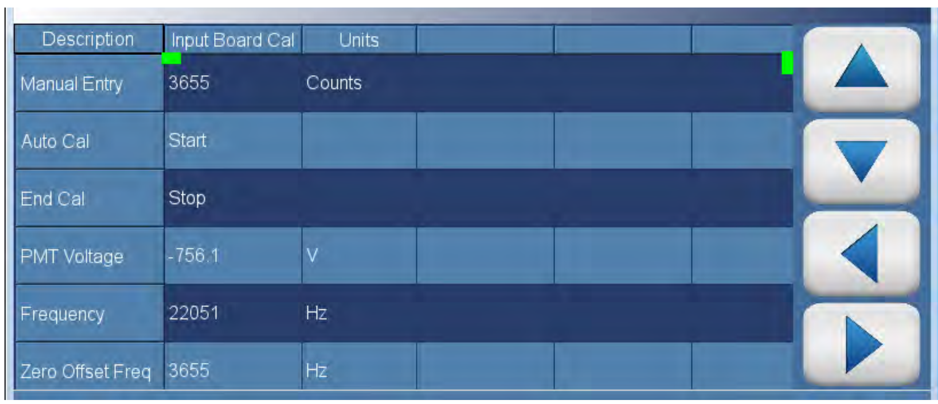
The Reaction Chamber Settings screen allows the user to calibrate the Input board and PMT.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Reaction Chamber Settings



Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Reaction Chamber Settings>Continue to Input Board Calibration Screen



The Input Board Calibration screen contains the following information:

- Across:
  - *Description:* Defines the actions the user can do.
  - *Input Board Cal:* User can manually adjust the input board value, start/stop automatic calibration, read voltage, frequency and zero offset frequency values, and reset default values.
  - *Units:* Displays units for each item.

- Down:
  - *Manual Entry:* Shows current value. If the input board cal cell is pressed, user can manually change the value.
  - *Auto Cal:* When pressed, the auto-calibration process is initiated. Please allow up to 5 minutes for calibration to complete.
  - *End Cal:* When pressed, the auto calibration is interrupted and the value does not change.
  - *PMT Voltage:* Displays PMT voltage.
  - *Frequency:* Displays frequency.
  - *Zero Offset Freq:* Displays zero offsets frequency.
  - *Default Values:* When pressed, the default values are saved.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Reaction Chamber Settings>Continue to PMT Calibration Screen

The PMT Calibration screen contains the following information:

- Across:
  - *Description:* Defines the actions the user can do.
  - *PMT Supply:* User can manually adjust the PMT supply value, adjust target concentration and read calibration concentration, start/stop automatic calibration, read voltage, frequency and zero offset frequency values, and reset default values.
  - *Current PMT:* Displays the current PMT voltage value.
  - *Units:* Displays units for each item.

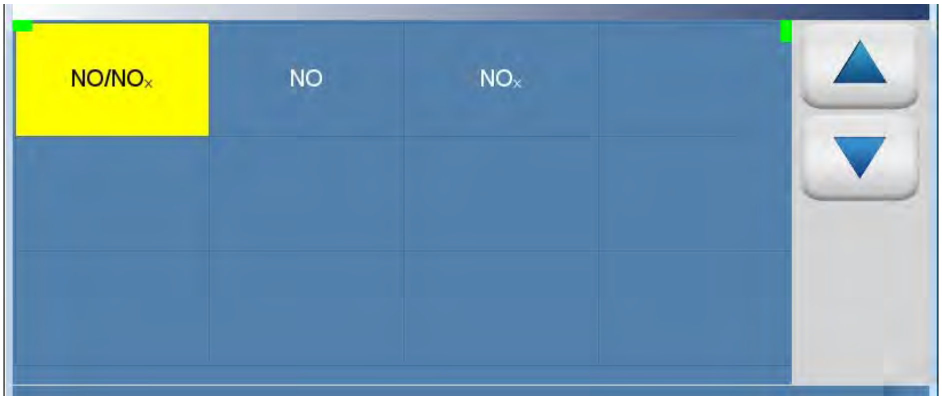
- Down:
  - *Manual Entry:* Shows current value. If the PMT supply cell is pressed, user can manually change the value.
  - *Target Concentration:* Displays target concentration. If target concentration cell is pressed, user can enter target concentration.
  - *Calibration Concentration:* Displays calibration concentration.
  - *Auto Calibration:* When pressed, the auto-calibration process is initiated. Please allow up to 5 minutes for calibration to complete. PMT voltage is automatically adjusted until calibration concentration is with 1% of target concentration.
  - *End Calibration:* When pressed, the auto calibration is interrupted and the value does not change.
  - *Default PMT Supply:* When pressed, the default PMT supply value is saved.

Auto/Manual Mode

The Auto/Manual Mode screen is used to display single gases or multiple gases (switching mode).

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Extended Ranges



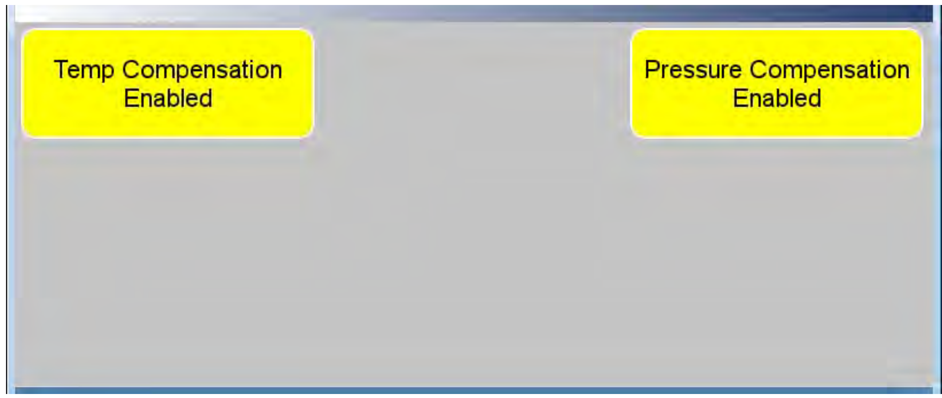
The Auto/Manual Mode screen contains the following information:

- NO/NO_x
- NO
- NO_x

Compensation

The Compensation screen provides compensation for any changes to the instrument's output signal due to internal instrument temperature, and pressure variations.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Compensation



The Compensation screen contains the following information:

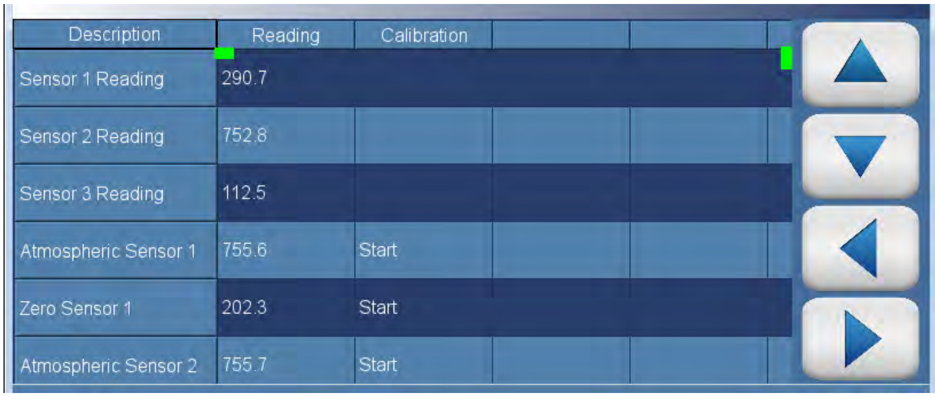
- *Temp Compensation:* Toggles temperature compensation enabled or disabled and provides compensation for any changes to the instrument's output signal due to internal instrument temperature variations. The effects of internal instrument temperature changes on the analyzer's subsystems and output have been empirically determined. This empirical data is used to compensate for any changes in temperature.
- *Pressure Compensation:* Toggles pressure compensation enabled or disabled and provides compensation for any changes to the instrument's output signal due to bench pressure variations. The effects of bench pressure changes on the analyzer's subsystems and output have been empirically determined. This empirical data is used to compensate for any change in bench pressure.

Pressure Calibration

The Pressure Calibration screen is used to calibrate the pressure sensor to zero, span, or factory default values.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Measurement Settings>Advanced Measurement Settings>Pressure Calibration



The Pressure Calibration screen contains the following information:

- Across:
  - *Description:* Lists items in table.
  - *Reading:* Displays reading of each pressure sensor.
  - *Calibration:* Starts calibration or resets default values.
- Down:
  - *Sensor 1–3 Reading:* Under the column labeled Reading, current reading of each pressure sensor.
  - *Atmospheric Sensor 1–3:* Under the column labeled reading, the user enters the current atmospheric pressure in mmHg units. Under the column labelled Calibration, the user presses the Start button to calibrate the high point of the sensor.
  - *Zero Sensor 1–3:* User should put the pressure sensor under a strong vacuum. Under the column labeled reading, the user enters the pressure in mmHg. Under the column labeled Calibration, the user presses the Start button to calibrate the low point of the sensor.
  - *Reset all values:* Resets values to default.

Communications

The Communications screen allows the user to set TCP/DHCP parameters, Serial settings, Analog I/O and Digital I/O, Email Server, and Instrument ID. Buttons are grayed out if not selected in Settings>**Configuration**.

Home Screen>Settings>More>Communications

The Communications screen contains the following information:

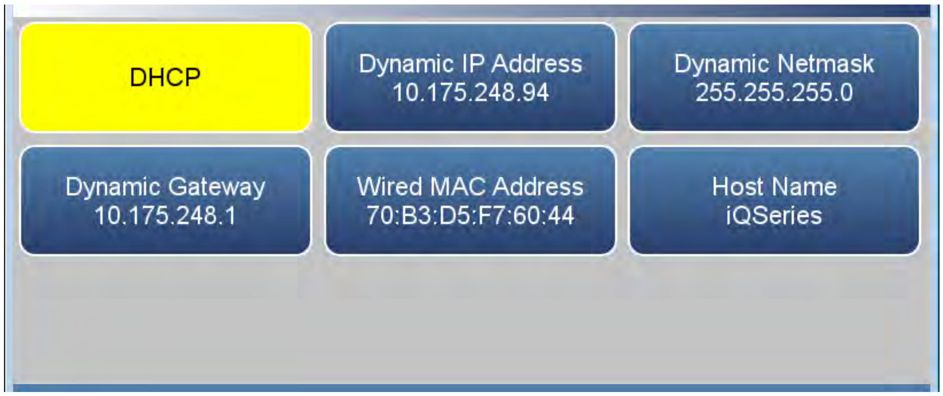
- *Wired TCP/DHCP:* Settings for communicating with the instrument through wired Ethernet.
- *Serial RS-232/485:* Settings for communicating with the instrument through RS-232/485 protocol. This is only visible if selected in Settings>Configuration>Communications Board.
- *Analog I/O:* Settings for communicating with the instrument through analog I/O settings. This is only visible if selected in Settings>Configuration>Analog I/O.
- *Digital I/O:* Settings for communicating with the instrument through digital I/O settings. This is only visible if selected in Settings>Configuration>Digital I/O.
- *Email Server (SMTP):* Settings for communication with email.
- *Instrument ID:* Allows the user to edit the instrument identification number (ID). The ID is used to identify the instrument when using protocols to control the instrument or collect data. It may be necessary to edit the ID number if two or more of instruments of the same model are connected to one computer. Valid instrument ID numbers are from 0 to 127. The 42iQ has a default instrument ID of 1.

Wired TCP/DHCP

The Wired TCP/DHCP screen allows the user to communicate with the instrument via wired TCP/IP settings.

Note When DHCP is enabled, the dynamic IP address is used. When DHCP is disabled, the static IP address is used. ▲

Home Screen>Settings>More>Communications> Wired TCP/DHCP (with DHCP enabled)



Home Screen>Settings>More>Communications>Wired TCP/DHCP (with DHCP disabled)

The Wired TCP/DHCP screen contains the following information:

- *DHCP:* Toggles DHCP enabled/disabled.
- *Dynamic IP Address:* Dynamic IP address of the instrument.
- *Dynamic Netmask:* Dynamic Netmask of instrument.
- *Dynamic Gateway:* Dynamic Gateway of instrument.

- *Static IP Address:* Static IP address of the instrument. This is settable when DHCP is disabled.
- *Static Netmask:* Static Netmask of instrument. This is settable when DHCP is disabled.
- *Static Gateway:* Static Gateway of instrument. This is settable when DHCP is disabled.
- *DNS Server Address:* DNS IP address of instrument. This is settable when DHCP is disabled.
- *Wired MAC Address:* Instrument MAC address.
- *Host Name:* Host name of instrument.

Serial RS-232/485

The Serial RS-232/485 screen allows the user to setup serial communication. This is only visible if selected in Settings>Configuration>**Communications Board**.

Home Screen>Settings>More>Communications>Serial RS-232/485

The Serial RS-232/485 screen contains the following information:

- *Protocol:* User selects Modbus or Streaming.
- *Baud Rate:* User selectable baud rates from 1200 to 115200.
- *Bits:* User selectable between 7 and 8.
- *Parity:* User selectable between None, Even, and Odd.
- *Stop Bits:* User selectable between 1 and 2.
- *RS 232/485:* User selectable between RS-232 and RS-485.

Analog I/O

The Analog I/O screen allows for configuring the analog inputs/outputs. This is only visible if selected in Settings>Configuration>**Analog I/O**.

Home Screen>Settings>More>Communications>Analog I/O

The Analog I/O screen contains the following information:

- *Analog In:* Allows the user to view and calibrate voltage inputs from external devices.
- *Analog Out (Voltage):* Allows the user to view voltage outputs.
- *Analog Out (Current):* Allows the user to view current (mA) outputs.
- *Analog Out Under/Over Range Enabled/Disabled:* Allows the user to select whether or not the analog outputs are allowed to exceed the selected output range.

Digital I/O

The Digital I/O screen allows for configuring the digital inputs/outputs. This is only visible if selected in Settings>Configuration>**Digital I/O**.

Home Screen>Settings>Communications>Digital I/O

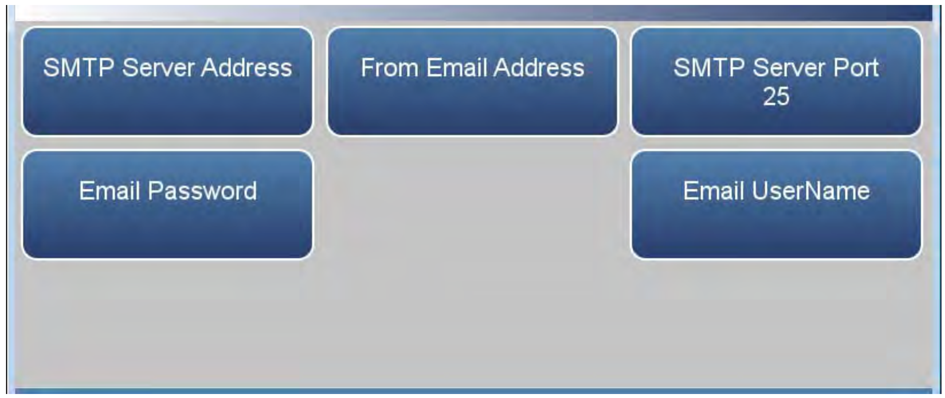
The Digital I/O screen contains the following information:

- *Digital In:* Allows the user to view digital inputs from external devices.
- *Digital Out (Relays):* Allows the user to view relay outputs.
- *Digital Out (Solenoids):* Allows the user to view solenoid outputs.
- *Advanced Digital I/O:* Allows user to test the digital out relays and solenoids.

Email Server (SMTP)

The Email Server (SMTP) screen allows the user to configure their email preferences.

Home Screen>Settings>More>Communications>Email Server (SMTP)



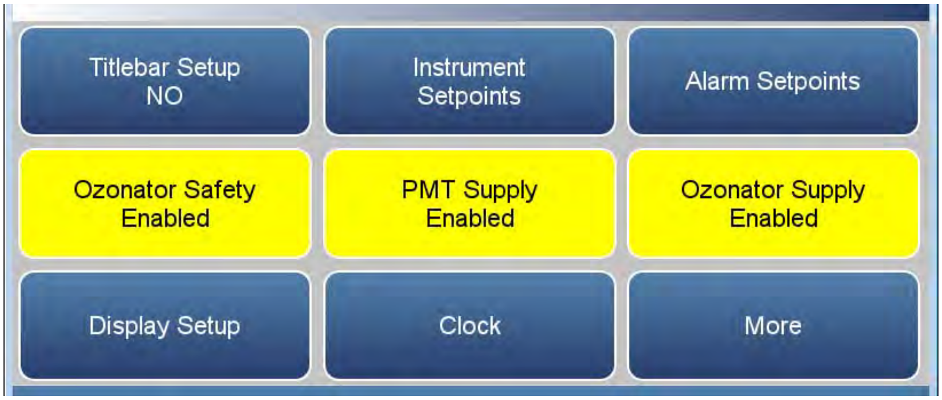
The Email Server (SMTP) screen contains the following information:

- *SMTP Server Address:* Address of the user's email server.
- *From Email Address:* The email address that goes in the From field in emails.
- *SMTP Server Port:* Server port of user's email server.
- *Email Password:* Password for SMTP server.
- *Email UserName:* User name that is authorized to send email through SMTP server.

Instrument Settings

The Instrument Settings screen allows the user to configure various instrument settings.

Home Screen>Settings>Instrument Settings



Home Screen>Settings>Instrument Settings>More

The Instrument Settings screen contains the following information:

- *Titlebar Setup:* User chooses what concentration reading to display on the titlebar.
- *Instrument Setpoints:* View and set all available setpoints.
- *Alarm Setpoints:* View and set all available alarm minimum and maximum values.
- *Ozonator Safety Enabled/Disabled:* Enables/disables ozonator safety.
- *PMT Supply Enabled/Disabled:* Enables/disables PMT supply.
- *Ozonator Supply Enabled/Disabled:* Enables/disables ozonator supply.
- *Display Setup:* Sets touchscreen display settings.
- *Clock:* Sets date and time.

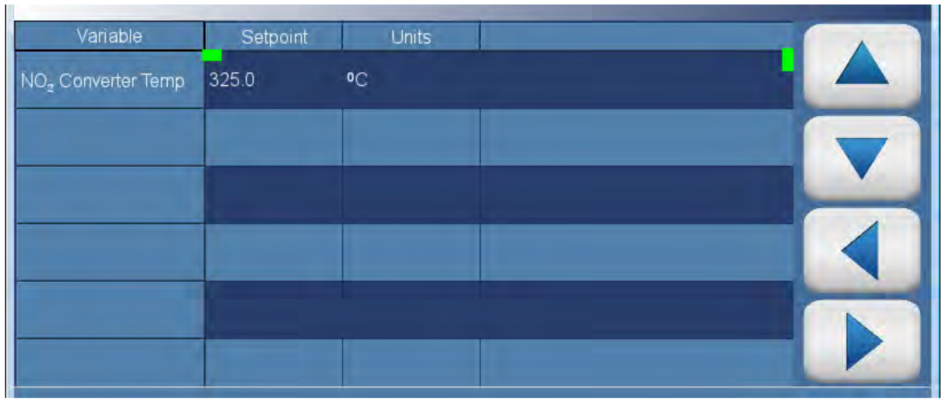
- *Language:* Read only.
- *Pump Power:* Manually enables/disables the pump.

Instrument Setpoints

The Instrument Setpoints screen allows the user to view and set all settable instrument minimum and maximum values.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Home Screen>Settings>Instrument Settings>Instrument Setpoints



The Alarm Setpoints screen contains the following information:

- Across:
  - *Variable:* Lists the items that have settable alarm limits.
  - *Setpoint:* User sets high alarm for item.
  - *Units:* Units for each item (not settable).
- Down:
  - *NO_2:Converter Temp:* NO_2 converter temperature.

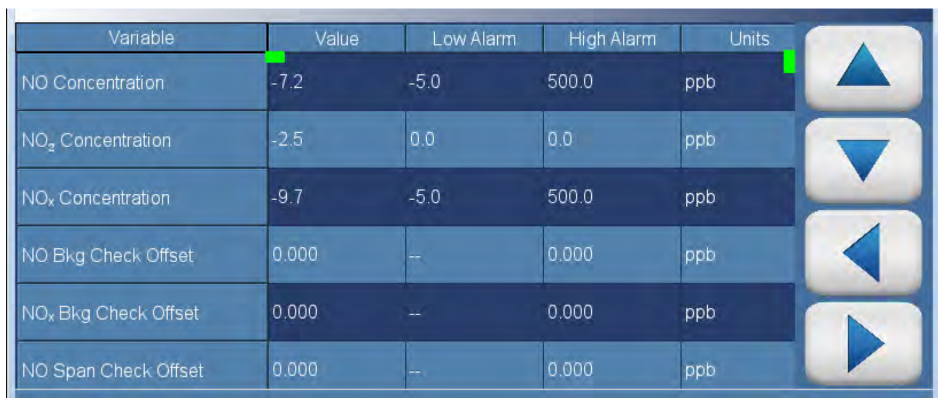
Alarm Setpoints

The Alarm Setpoints screen allows the user to view and set all settable alarm minimum and maximum values. Alarm setpoints can also be set in Settings>Health Check>Status and Alarms screens.

Use the ▲ and ▼ buttons to move up and down and the ◀ and ▶ buttons to move left and right.

Note User cannot set alarm limits outside of the acceptable range. The minimum and maximum alarm limit can also be set by pressing on the corresponding buttons located in the Settings>Health Check>Status and Alarms screen. See "Status and Alarms" on page 3-46. ▲

Home Screen>Settings>Instrument Settings>Alarm Setpoints



The Alarm Setpoints screen contains the following information:

- Across:
  - *Variable:* Lists the items that have settable alarm limits.
  - *Low Alarm:* User sets low alarm for item.
  - *High Alarm:* User sets high alarm for item.
  - *Units:* Units for each item (not settable).
- Down:
  - *NO:* NO concentration alarm.
  - *NO_2:* NO_2 concentration alarm.
  - *NO_x:* NO_x concentration alarm.

- *NO Bkg Check Offset:* User can set the maximum allowable background reading offset for calibration and calibration checks. This is set with the high alarm only.
- *NO_x Bkg Check Offset:* User can set the maximum allowable background reading offset for calibration and calibration checks. This is set with the high alarm only.
- *NO Span Check Offset:* User can set the maximum allowable span reading offset for calibration and calibration checks. This is set with the high alarm only.
- *NO_x Span Check Offset:* User can set the maximum allowable span reading offset for calibration and calibration checks. This is set with the high alarm only.
- *Instrument Temperature:* Instrument temperature alarm.
- *Chamber Pressure:* Bench pressure alarm.
- *Flow:* Flow pressure alarm.
- *Chamber Temperature:* Bench temperature alarm.
- *Cooler Temperature:* Cooler temperature alarm.
- *NO_2 Converter Temperature:* NO_2 converter temperature alarm.
- *Perm Oven Temperature:* Perm oven temperature alarm.

Display Setup

The Display Setup allows the user to change the brightness of the display and choose power save option.

Home Screen>Settings>Instrument Settings>Display Setup

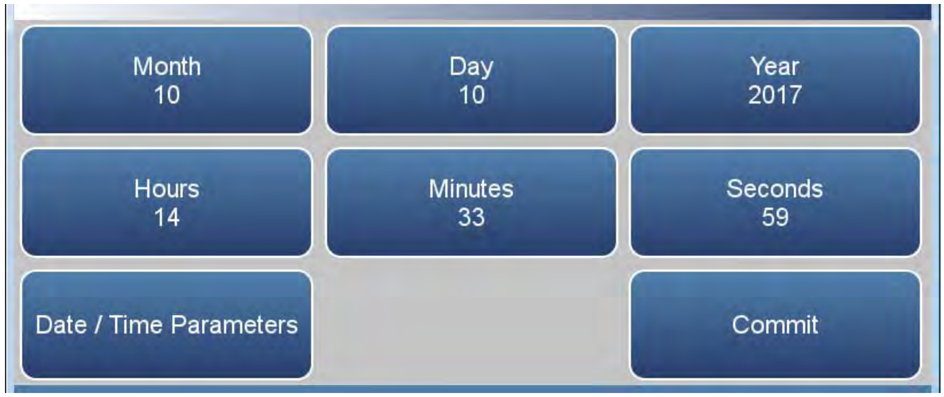
The Display Setup screen contains the following information:

- *Power Save:* Minutes before screen times out. Toggles enable/disable.
- *Power Save Setting:* Option whereby the user can display a black screen after a set amount of inactivity.
- *Brightness:* Sets the brightness of the display.

Clock

The Clock screen allows the user to set the instrument's date and time, choose date/time format, time zone, and time server.

Home Screen>Settings>Instrument Settings>Clock



The Clock screen contains the following information:

- Month
- Day
- Year
- Hours
- Minutes
- Seconds
- *Date / Time Parameters:* User chooses time zone, timer server, and date format.
- *Commit:* When pressed, date and time are saved.

Date / Time Parameters

The Date / Time Parameters screen allows the user to choose time zone, time server and date format.

Home Screen>Settings>Instrument Settings>Clock>Date / Time Parameters

The Date / Time Parameters screen contains the following information:

- *Time Zone:* User selects time zone from table.
- *Time Server Enabled/Disabled:* User can enabled/disable the time server to get periodic clock updates.
- *Date Format:* User selects date format.

Time Zone

The Time Zone screen allows the user to set the time zone for the Network Time Protocol (NTP) server. This should be set to the time zone that the instrument is located in.

Use the ▲ and ▼ buttons to move up and down.

Home Screen>Settings>Instrument Settings>Clock>Date / Time Parameters>Time Zone

The Time Zone screen contains the following information:

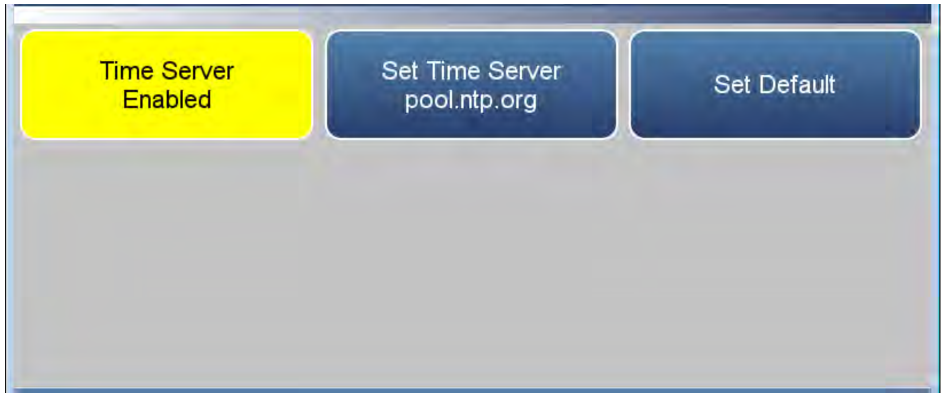
- Date Line West(UTC-12)
- Samoa Time Zone(UTC-11)
- Aleutian Time Zone(UTC-10)
- Alaskan Time Zone(UTC-9)
- Pacific Time Zone(UTC-8)
- Pacific Daylight Savings(UTC-7)
- Mountain Time Zone(UTC-7)
- Mountain Daylight Savings(UTC-6)
- Central Time Zone(UTC-6)
- Central Daylight Savings((UTC-5)
- Eastern Time Zone(UTC-5)
- Eastern Daylight Savings(UTC-4)
- Atlantic Time Zone(UTC-4)
- Mid-Atlantic(UTC-3)
- South Georgia(UTC-2)

- Cape Verde Time(UTC-1)
- Coordinated Universal Time(UTC-0)
- Central European Time(UTC+1)
- Eastern European Time(UTC+2)
- Further-Eastern European Time(UTC+3)
- Gulf Standard Time(UTC+4)
- Yekaterinburg Time(UTC+5
- Omsk Time(UTC+6)
- Indochina Time(UTC+7)
- ASEAN Common Time(UTC+8)
- Japan Standard Time(UTC+9)
- Chamorro Time Zone(UTC+10)
- Sredmnekolymsk Time(UTC+11)
- New Zealand Standard Time(UTC+12)

Time Server

The Time Server screen allows the user to enable/disable the time server to get periodic clock updates.

Home Screen>Settings>Instrument Settings>Clock>Date / Time Parameters>Time Server



The Time Server screen contains the following information:

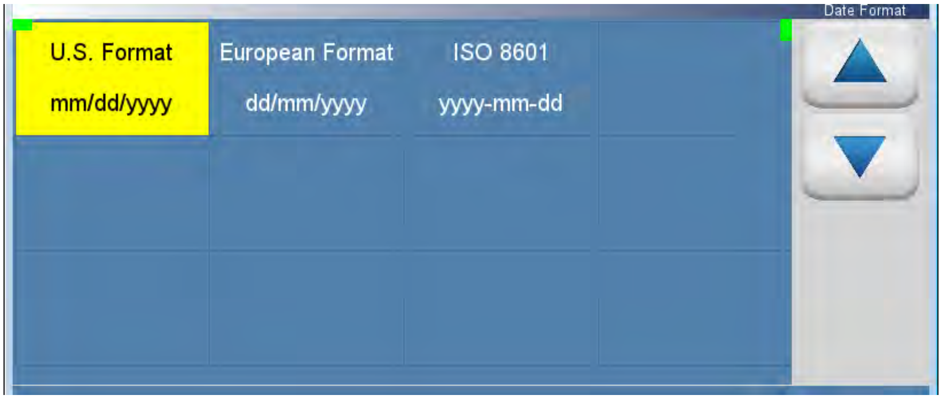
- *Time Server:* Enables/Disables periodic clock updates from an NTP (Network Time Protocol) source.
- *Set Time Server:* User can choose specific time server.
- *Set Default:* When pressed, default time server will be used.

Date Format

The Date Format screen allows the user to choose from the following formats: mm/dd/yyyy, dd/mm/yyyy or yyyy-mm-dd.

Use the ▲ and ▼ buttons to move up and down.

Home Screen>Settings>Instrument Settings>Clock>Date / Time Parameters>Date Format



The Date Format screen contains the following information:

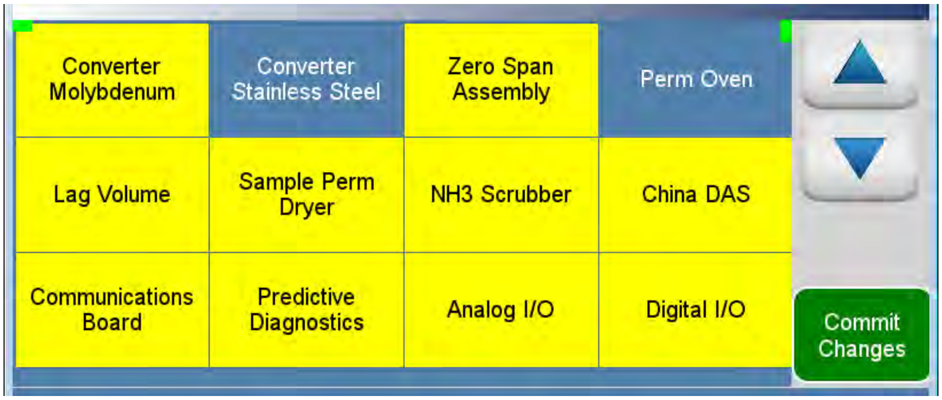
- U.S. Format mm/dd/yyyy
- European Format dd/mm/yyyy
- ISO 8601 yyyy-mm-dd

Configuration

The Configuration screen allows the user to enable optional features.

Use the ▲ and ▼ buttons to select the variables. Next, press the **Commit Changes** button to save selections. Yellow buttons indicate that the variable is selected. More than one can be chosen.

Home Screen>Settings>Configuration



The Configuration screen contains the following information:

- *Converter Molybdenum:* Select if molybdenum converter is used.
- *Converter Stainless Steel:* Select if stainless steel converter is used.
- *Zero Span Assembly:* Enables zero/span valves.
- *Perm Oven:* Enables permeation oven option.
- *Lag Volume:* Installed hardware option. .
- *Sample Perm Dryer:* Removes moisture from sample.
- *NH3 Scrubber:* Removes NH_3 from sample.
- *Communications Board:* Enables RS-232 or RS-485 communication board.
- *Predictive Diagnostics:* Enables predictive diagnostics.
- *Analog I/O:* Enables analog I/O option.
- *Digital I/O:* Enables digital I/O option.

Security Access Levels

The Access Levels screen allows the user to set the instrument to either View Only or Full Access. When in Full Access, the user will have access to all screens. When set to View Only, user will not be able to change any values.

Home Screen>Settings>Security Access Levels (Full Access)

Home Screen>Settings>Security Access Levels (View Only Access)

The Security Access Levels screen contains the following information:

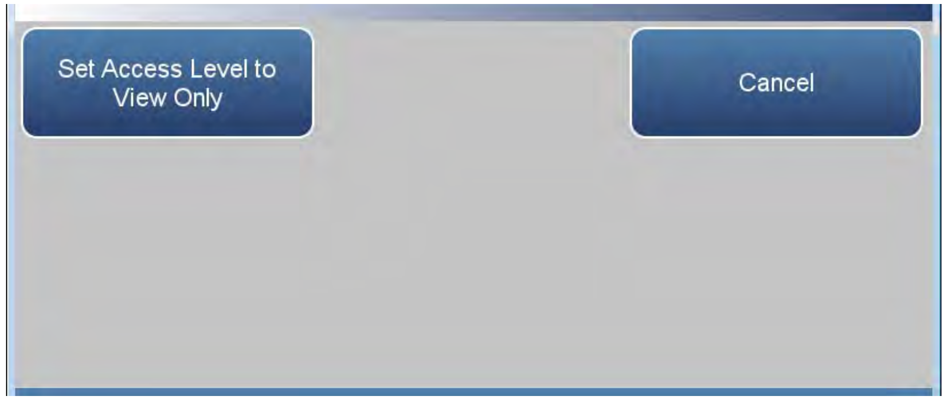
- *Current Security Access Full Access:* Read only. User will be able to change all values. Password is needed for full access.
- *Current Security Access View Only:* Read only. User won't be able to change any values. Password is not needed for view only.
- *Change Security Access to View Only:* User can switch to view only mode. Password not needed to change settings to view only access.
- *Change Security Access to Full Access:* User can switch to full access mode. Password is needed to change settings to full access.

- *Change Full Access Security Password:* Full access password can have a blank value or user selected password.

Change Security to View Only Access

The Change Security to View Only Access screen allows the user to set the instrument to view only.

Home Screen>Settings>Security Access Levels>Change Security Access to View Only Access



The Change Security to View Only Access screen contains the following information:

- *Set Access Level to View Only:* Programs the instrument to be in the view only access level, where the user won't be able to change any values.
- *Cancel:* Exit screen.

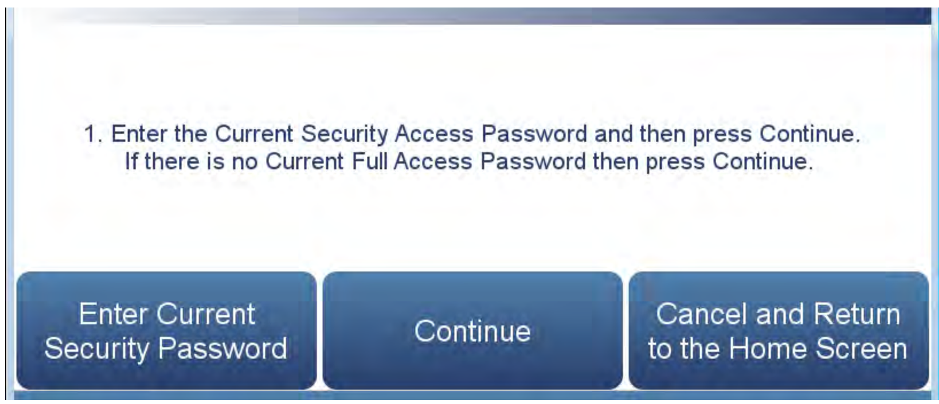
Note To change security access from view only access to full access, a keypad will be displayed where the user can enter full access password. ▲

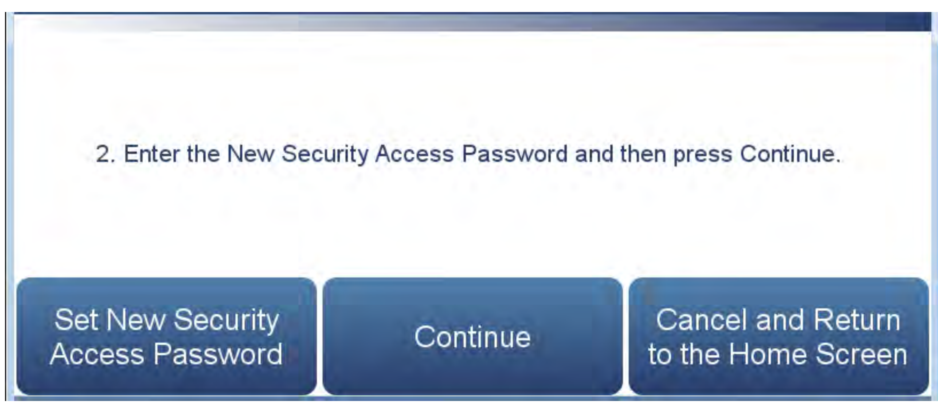
Change Full Access Security Password

The Change Full Access Security Password screen allows the user to set a new password for allowing full access.

Home Screen>Settings>Security Access Levels>Change Full Access Security Password

Home Screen>Settings>Security Access Levels>Change Full Access Security Password>Continue





The Change Full Access Security Password screens contain the following information:

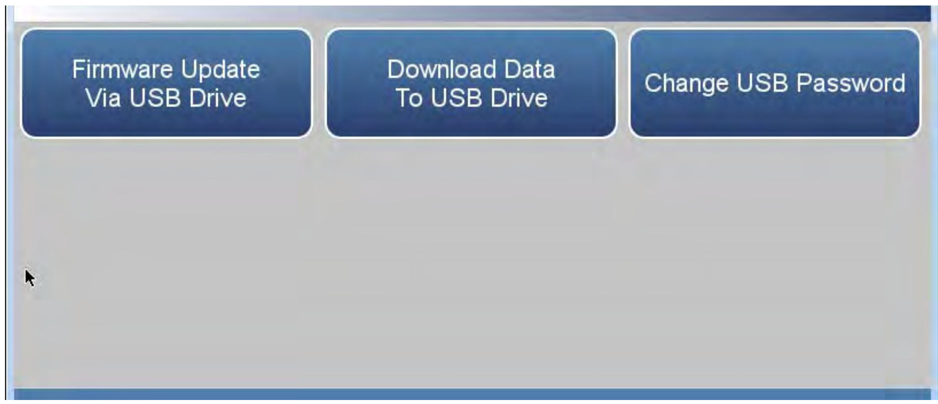
- *Enter Current Security Password:* User enters current security password.
- *Continue:* Proceeds to next screen.
- *Enter New Security Access Password:* User enters new security password.
- *Confirm New Security Access Password:* User confirms new security password for spelling confirmation.
- *Commit New Security Access Password Change:* Commits new security password.
- *Cancel and Return to the Home Screen:* Exits screen and returns to the Home Screen without changing password.

USB Drive

The USB Drive screen allows the user to update firmware, download/upload information, and change the USB password.

Note The USB drive screen only is useable when a USB drive is inserted into the USB port. When a USB drive is inserted, the user is prompted to enter the password if a password has been set. ▲

Home Screen>Settings>USB Drive



The USB Drive screen contains the following information:

- *Firmware Update Via USB Drive:* If USB is mounted, user can update instrument firmware.
- *Download Data To USB Drive:* User can download/upload information.
- *Change USB Password:* User can change the USB password.

Firmware Update Via USB Drive

The Firmware Update Via USB Drive screen allows the user to update instrument firmware from the USB drive.

Home Screen>Settings>USB Drive>Firmware Update Via USB Drive

The Firmware Update Via USB Drive screen contains the following information:

- *Update Firmware:* User chooses firmware file from USB and updates instrument firmware. Instrument reboots when update is finished.
- *Exit:* User exits without updating firmware.

Download Data To USB Drive

The Download Data To USB Drive screen allows the user to download/upload data to/from the USB drive.

Home Screen>Settings>USB Drive>Download Data To USB Drive

The Download Data to USB Drive screen contains the following information:

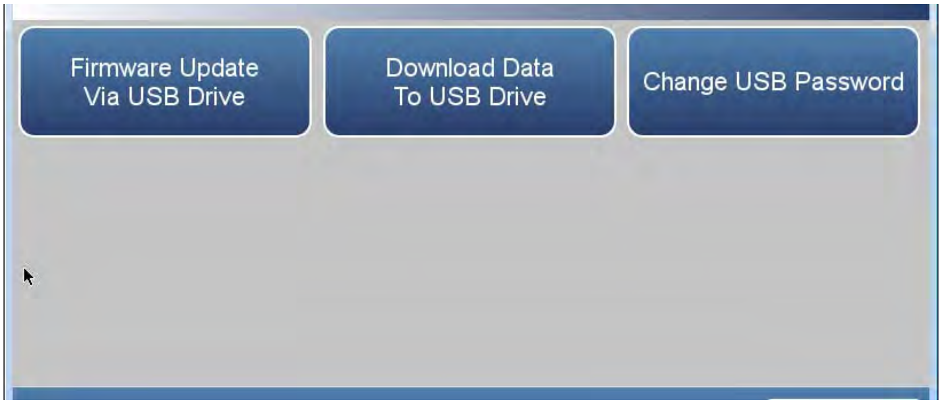
- *Download Health Check Report:* Includes status and alarms, preventive maintenance, and maintenance history.
- *Download Entire Data Log:* Includes the entire data log (from data logging).
- *Download Service Log:* Includes a complete listing of data for all variables. This is set at the factory.
- *Download System Log:* Consists of system log text files, which include a listing of system errors.
- *Download Calibration History:* Includes the data in the calibration history screen.
- *Download Configuration Data Backup to USB:* Allows the user to download the configuration file from the instrument to the USB.
- *Upload Configuration Data Restore from USB:* Allows the user to upload the configuration files from the USB to the instrument.
- *Restore:* Allows the user to upload the configuration files from the USB to the instrument.
- *Download All Data:* Downloads all reports, logs, histories, and backup information.

Use the following procedure to download data using the USB connection.

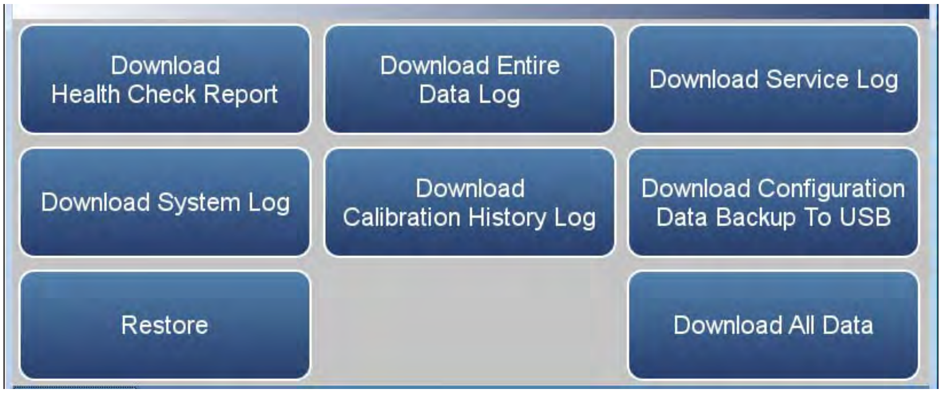
1. Plug a flash drive into the USB connection on the front of the instrument. If a USB password has been previously set, you will be prompted to enter the USB password to continue. Press **Enter** to continue.

2. To continue, select the **OK** button.

3. The USB Drive will display. Select **Download Data To USB Drive**.



4. The Download Data to USB Drive screen will display. Select from various options to download.



5. The instrument will display a "downloading data" message and begin transferring data to the USB drive.

Note Do not remove the USB drive from the instrument while the data is downloading. ▲

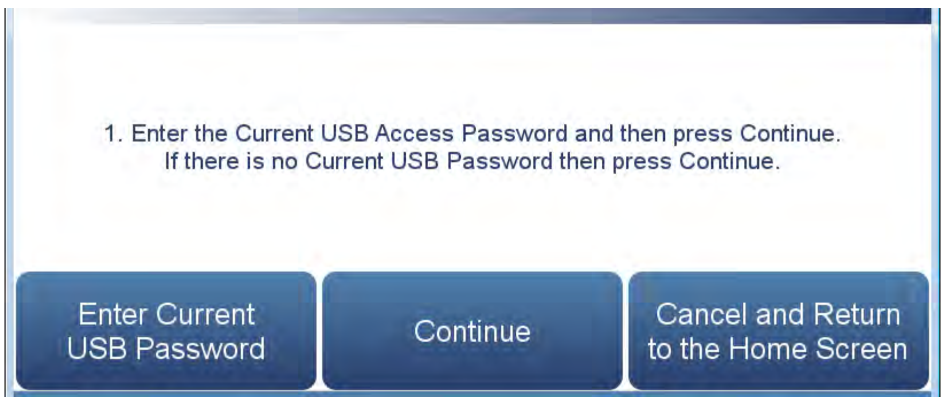
6. When the data download is complete, the instrument will display a "Success!" message and display the file name as it is stored on the USB flash drive. (The file name format is the instrument serial number, name of download, followed by a date/time stamp.) Remove the USB flash drive and select the OK button to continue.

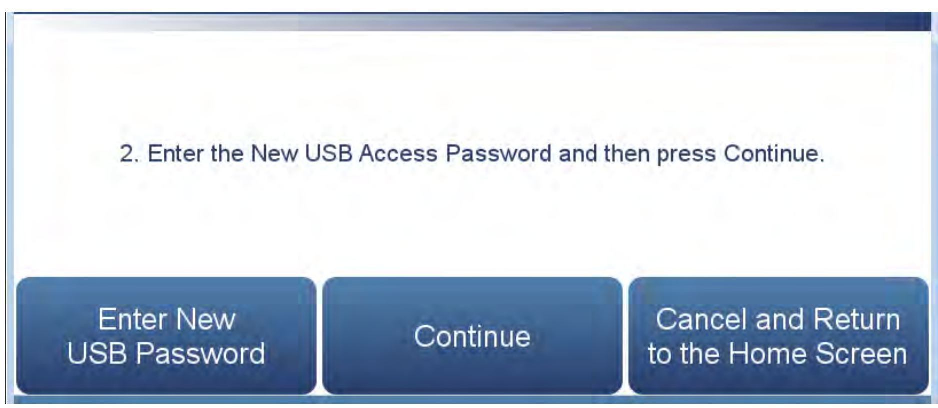
Change USB Password

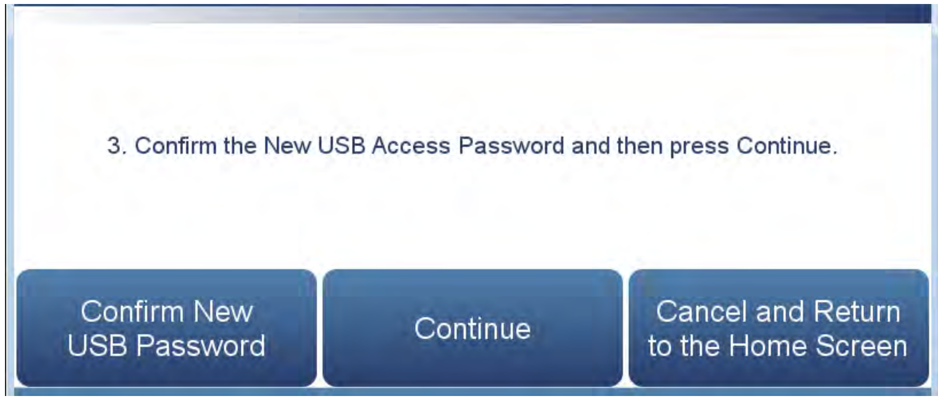
The Change USB Password screen allows the user to set a new password for accessing USB.

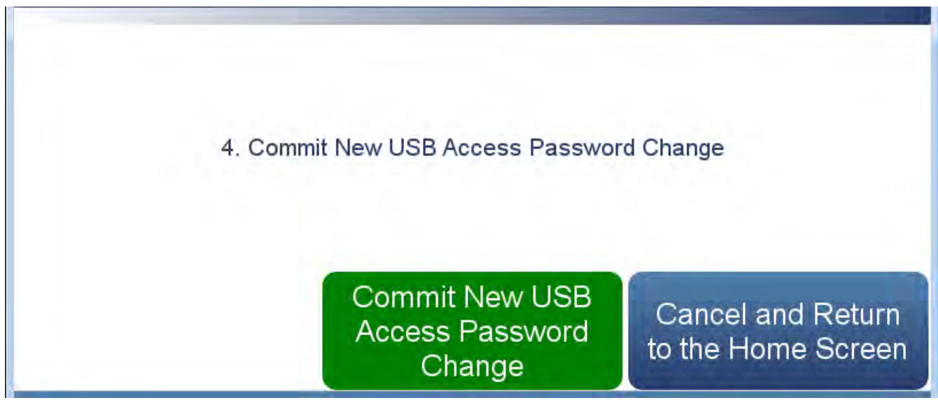
Home Screen>Settings>USB Drive>Change USB Password

Home Screen>Settings>Security Access Levels>Change Standard Access Password>Continue









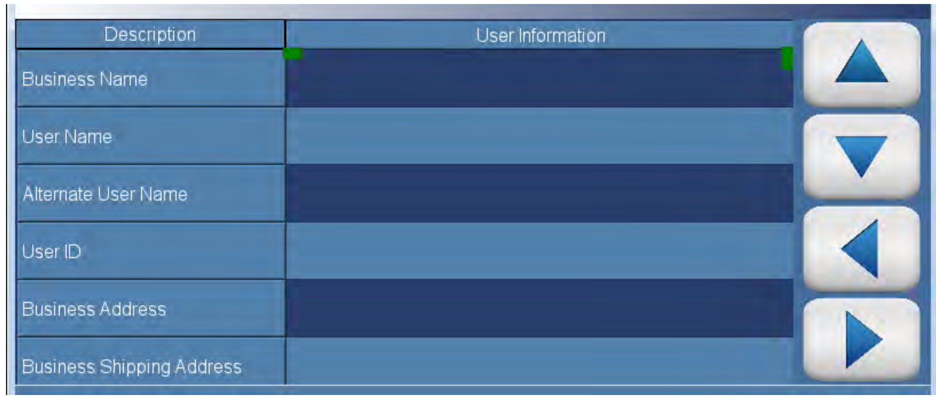
The Change USB Password screens contain the following information:

- *Enter Current USB Password:* User enters current USB password.
- *Continue:* Proceeds to next screen.
- *Enter New USB Password:* User enters new USB password.
- *Confirm New Security Access Password:* User confirms new security password for spelling confirmation.
- *Commit New USB Password Change:* Commits new USB password.
- *Cancel and Return to the Home Screen:* Exits screen and returns to the Home Screen without changing password.

User Contact Information

The User Contact Information screen allows the user to enter their contact information. This is useful when contacting technical support through emails found at the screen Health Check>File Sharing and Support.

Home Screen>Settings>User Contact Information



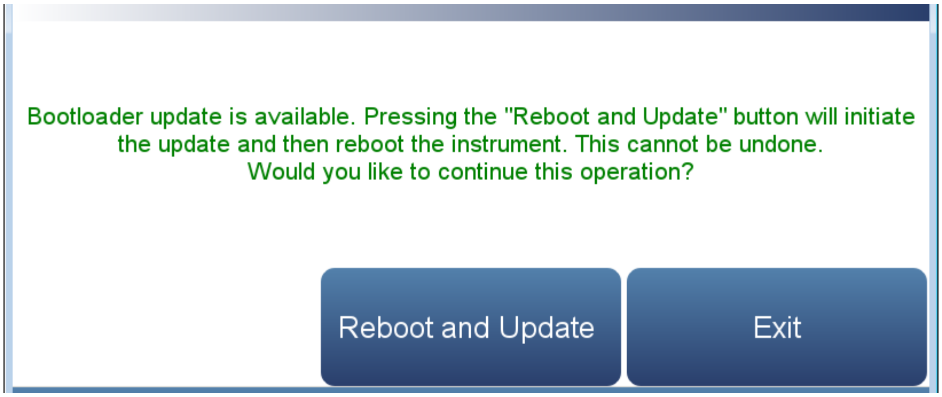
The User Contact Information screen contains the following information:

- Business Name
- User Name
- Alternate User Name
- User ID
- Business Address
- Business Shipping Address
- To: User Email Address
- CC: User Email Address 1–10
- User Phone Number
- Alternate User Phone Number
- Shelter / Lab Phone Number

Update Bootloader

The Update Bootloader screen allows the user to update bootloader and reboot the instrument. If the button is blue, an update to the bootloader is available. If button is greyed out, no update is needed.

Home Screen>Settings>Update Bootloader



The Update Bootloader screen contains the following information:

- *Reboot and Update:* Update bootloader and reboot instrument.
- *Exit:* Exits screen.

Chapter 4
Calibration

This chapter describes the procedures for performing a standard zero/span calibration.

The 42iQ requires initial and periodic calibration according to the procedures described in this chapter. A quality control plan that allows the frequency and number of calibration points to be modified depending on calibration and zero/span check data should be implemented. Such a quality control program is essential to ascertain the accuracy and reliability of the air quality data collected. The data compiled for such a program might include items such as dates of calibration, atmospheric conditions, control settings and other pertinent data. For more detailed quality assurance guidelines, see the *Quality Assurance Handbook for Air Pollution Measurement Systems*, published by the U.S. EPA, Research Triangle Park, NC, 27711.

There are a number of conditions which should be met prior to a calibration or a zero/span check. First, the instrument should have at least 90 minutes to warm up and stabilize. Second, the range used during the calibration or zero/span check should be the same as that used during normal monitoring. Third, all operational adjustments to the instrument should be completed prior to calibration. Fourth, all parts of the gas flow system, such as sample lines, and particulate filters, which are used in normal monitoring, should also be used during calibration. Finally, it is recommended that the recording devices and outputs used during normal monitoring be calibrated prior to the instrument calibration and that they be used during the calibration or the zero/span check.

The following describes procedures for performing a multipoint calibration of the 42iQ. The information described here is considered adequate to perform the calibration. However, if greater detail is desired, the user is referred to the Code of Federal Regulations, Title 40, Part 50, Appendix F.

The calibration technique is based on the rapid gas phase reaction between NO and O_3 which produces stoichiometric quantities of NO_2 in accordance with the reaction:

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

The quantitative nature of this reaction is such that when the NO concentration is known, the concentration of NO_2 can be determined. Ozone is added to excess NO in a dynamic calibration system, and the NO channel of the chemiluminescence NO-NO_2-NO_x analyzer is used as an indicator of changes in NO concentration.

When O_3 is added, the decrease in NO concentration observed on the calibrated NO channel is equivalent to the concentration of NO_2 produced. Adding variable amounts of O_3 from a stable O_3 generator can change the amount of NO_2 generated.

Equipment Required

The following equipment is required to calibrate the analyzer:

- Zero gas generator
- Gas phase titrator

Zero Gas Generator

A zero air source, such as a Thermo Scientific *111iQ Zero Air Supply*, free of contaminants such as NO, NO_2, and O_3 is required for dilution, calibration, and gas phase titration.

Compression

The zero air source should be at an elevated pressure to allow accurate and reproducible flow control and to aid in subsequent operations such as drying, oxidation, and scrubbing. An air compressor that gives an output of 10 psig is usually sufficient for most applications.

Drying

Several drying methods are available. Passing the compressed air through a bed of silica gel, using a heatless air dryer, or removing water vapor with a permeation dryer, are three possible approaches.

Oxidation

NO is usually oxidized to NO_2 in order to ease its scrubbing. Oxidation can be accomplished by either ozonation or chemical contact. During ozonation, the air is passed through an ozone generator. The O_3 that is produced reacts with the NO to form NO_2. Care must be taken to allow sufficient residence time for the ozonation reaction to go to completion.

Chemical oxidation is accomplished by passing the air stream through a reacting bed. Such agents as CrO_3 on an alumina support or Purafil® are very efficient at oxidizing NO to NO_2. The chemical contact approach has the advantage of needing no electrical power input for its application.

Scrubbing

Fixed bed reactors are commonly used in the last step of zero air generation to remove the remaining contaminants by either further reaction or absorption. Table 4–1 lists materials that can be effective in removing contaminants.

Table 4–1. Scrubbing Materials

To Remove	Use
NO	Soda-Lime (6-12 mesh), Purafil
Hydrocarbons	Molecular Sieve (4A), Activated Charcoal
O_3 and NO_2	Activated Charcoal

Gas Phase Titrator

A gas phase titrator (GPT), such as is included in the Thermo Scientific 146iQ Multi-gas Calibrator, is used to generate NO_2 concentrations from NO concentrations. Figure 4–1 shows the suggested placement of the component parts of a gas phase titration apparatus.

Equipment Damage All connections between components in the system should be made with glass, PTFE, or other non-reactive material. ▲

Flow Controllers

The airflow controllers should be devices capable of maintaining constant airflows within ±2% of the required flow rate. The NO flow controller should be capable of maintaining constant NO flows within ±2% of the required flow rate.

Pressure Regulator

The pressure regulator for the standard NO cylinder must have a non-reactive diaphragm and internal parts, and a suitable delivery pressure.

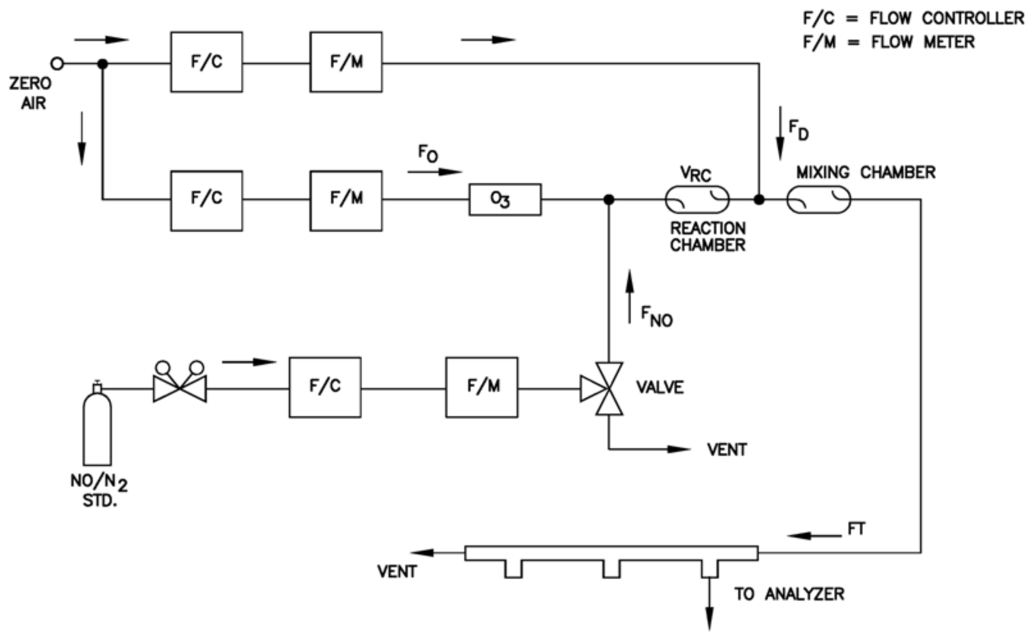


Figure 4–1. GPT System

Ozone Generator

The ozone generator must be capable of generating sufficient and stable levels of ozone for reaction with NO to generate NO_2 concentrations in the range required.

Note Ozone generators of the electric discharge type may produce NO and NO_2 and are not recommended. ▲

Diverter Valve

A valve can be used to divert the NO flow when zero air is required at the manifold.

Reaction Chamber

The reaction chamber used for the reaction of ozone with excess NO should have sufficient volume so that the residence time meets the requirements specified in this chapter.

Mixing Chamber

The mixing chamber is used to provide thorough mixing of the reaction products and diluent air.

Output Manifold

The output manifold should be of sufficient diameter to insure an insignificant pressure drop at the analyzer connection. The system must have a vent designed to insure atmospheric pressure at the manifold and to prevent ambient air from entering the manifold.

Reagents

The following information describes the NO concentration standard and the method for calculating the NO concentration standard and the NO_2 impurity.

NO Concentration Standard

A cylinder containing 10 to 50 ppm NO in N_2 with less than 1 ppm NO_2 is usually used as the concentration standard. The cylinder must be traceable to a National Institute of Standards and Technology (NIST) NO in N_2 Standard Reference Material or NO_2 Standard Reference Material.

Procedures for certifying the NO cylinder (working standard) against an NIST traceable NO or NO_2 standard and for determining the amount of NO_2 impurity are given in EPA Publication No. EPA-600/4-75-003, "Technical Assistance Document for the Chemiluminescence Measurement of Nitrogen Dioxide."

In addition, the procedure for the certification of a NO working standard against an NIST traceable NO standard and determination of the amount of NO_2 impurity in the working standard is reproduced here. The cylinder should be re-certified on a regular basis as determined by the local quality control program.

Use the NIST traceable NO standard and the GPT calibration procedure to calibrate the NO, NO_2, and NO_x responses of the instrument. Also determine the converter efficiency of the analyzer. Refer to the calibration procedure in this manual and in the Code of Federal Regulations, Title 40, Part 50, Appendix F for exact details. Ignore the recommended zero offset adjustments.

Assaying a Working NO Standard Against a NIST-traceable NO Standard

Use the following procedure to calculate the NO concentration standard and NO_2 impurity.

1. Generate several NO concentrations by dilution of the NO working standard.

2. Use the nominal NO concentration, $[NO]_{NOM}$, to calculate the diluted concentrations.

3. Plot the analyzer NO response (in ppm) versus the nominal diluted NO concentration and determine the slope, S_{NOM}.

4. Calculate the [NO] concentration of the working standard, $[NO]_{STD}$, from:

$$[NO]_{STD} = [NO]_{NOM} \text{ x } S_{NOM}$$

5. If the nominal NO concentration of the working standard is unknown, generate several NO concentrations to give on-scale NO responses.

6. Measure and record F_{NO} and F_T for each NO concentration generated.

7. Plot the analyzer NO response versus F_{NO}/F_T and determine the slope which gives $[NO]_{STD}$ directly. The analyzer NO_x responses to the generated NO concentrations reflect any NO_2 impurity in the NO working standard.

8. Plot the difference between the analyzer NO_x and NO responses versus F_{NO}/F_T. The slope of this plot is $[NO_2]_{IMP}$.

Zero Air

A source of zero air free of contaminants should be used as described earlier in this chapter. Contaminants can cause a detectable response on the instrument and may also react with the NO, O_3, or NO_2 during the gas phase titration.

Dynamic Parameter Specifications for Gas Titrator

Use the following definitions for the remainder of this chapter.

P_R =	Dynamic parameter specification to ensure complete reaction of the available O_3, ppm-min
$[NO]_{RC}$ =	NO concentration in the reaction chamber, ppm
t_R =	residence time of the reactant gases in the reaction chamber, min
$[NO]_{STD}$ =	Concentration of the undiluted NO standard, ppm
F_{NO} =	NO flow rate, sccm
F_O =	O_3 generator air flow rate, sccm
V_{RC} =	Volume of the reaction chamber, cc
F_T =	Analyzer demand plus 10 to 50% excess

The O_3 generator (ozonator) airflow rate and the NO flow rate must be adjusted such that the following relationships hold:

$$P_R = [NO]_{RC} \text{ x } t_R \geq 2.75 \text{ppm-min}$$

$$[NO]_{RC} = [NO]_{STD} \frac{F_{NO}}{(F_O + F_{NO})}$$

$$t_R = \frac{V_{RC}}{F_O + F_{NO}} < 2 \text{ min}$$

Determining GPT System Flow Conditions

Use the following procedure to determine the flow conditions to be used in the GPT system.

1. Determine FT, the total flow required at the output manifold, which should be equal to the analyzer demand plus 10 to 50 percent excess.

2. Establish $[NO]_{OUT}$ as the highest NO concentration that will be required at the output manifold. $[NO]_{OUT}$ should be about equal to 90% of the upper range limit (URL) of the NO_2 concentration range to be covered.

3. Determine F_{NO} as:

$$F_{NO} = \frac{[NO]_{OUT} \text{ x } F_T}{[NO]_{STD}}$$

4. Select a convenient or available reaction chamber volume. Initially a trial volume may be selected in the range of 200 to 500 cc.

5. Compute F_O as:

$$F_O = \sqrt{\frac{[NO]_{STD} \text{ x } F_{NO} \text{ x } V_{RC}}{2.75}} - F_{NO}$$

6. Compute t_R as:

$$t_R = \frac{V_{RC}}{F_O + F_{NO}}$$

7. Verify that $t_R < 2$ minutes. If not, select a reaction chamber with a smaller V_{RC}.

8. Compute the diluent air flow rate as:

$$F_D = F_T - F_O - F_{NO}$$

9. If F_O turns out to be impractical for the desired system, select a reaction chamber having a different V_{RC} and recompute F_D and F_O.

Pre-Calibration

Perform the following pre-calibration procedure before calibrating the 42iQ. For detailed information about the menu parameters and the icons used in these procedures, see the "Operation" chapter.

Note The calibration and calibration check duration times should be long enough to account for the transition (purge) process when switching from sample to zero and from zero to span. This transition time is the time required to purge the existing air. ▲

Note Depending on the plumbing configuration and the instrument, data from approximately the first minute of a zero calibration or check should be disregarded because of residual sample air. Also, data from approximately the first minute of a span calibration or check should be disregarded because the span is mixing with the residual zero air. ▲

1. Allow the instrument to warm up and stabilize.

2. Be sure the ozonator is enabled. If the ozonator is disabled:

   a. From the Home screen choose **Settings>Instrument Settings**.

   b. Press **Ozonator Supply** to toggle the ozonator to show **Enabled**.

3. Be sure the instrument is in the auto mode, that is, NO, NO_2, and NO_x measurements are being displayed on the front panel display. If the instrument is not in auto mode:
   a. From the Home screen choose **Settings>Measurement Settings>Advanced Measurement Settings>Auto/Manual Mode**.
   b. Select **NO/NOx**.

4. Check the averaging time. It is recommended that a higher averaging time be used for best results.
   a. From the Home screen choose **Settings>Measurement Settings>Averaging time**. (Ensure Dynamic Filtering is disabled to access Averaging Time.)

Note The averaging time should be less than the zero duration and less than the span duration. ▲

5. Verify that any filters used during normal monitoring are also used during calibration.

Calibration

The following procedure calibrates the analyzer using the gas phase titrator and zero in gas generator described previously in this manual. It is suggested that a calibration curve have at least seven points between the zero and full scale NO concentrations. Although the seven-point curve is optional, two of whatever number of points is chosen should be located at the zero and 90% levels and the remaining points equally spaced between these values.

Note When the instrument is equipped with internal zero/span and sample valves, the ZERO IN and SPAN ports should give identical responses to the SAMPLE port when test gases are introduced. The user should calibrate the instrument using the SAMPLE port to introduce the zero and span gas sources. ▲

After calibration, the zero in and span sources should be plumbed to the appropriate ports on the rear panel of the instrument, and then reintroduced to the instrument. The instrument should give identical responses to the test gases whether they are introduced via the SAMPLE port or the ZERO IN or SPAN ports. If not, the plumbing and/or valves should be serviced.

Connect GPT Apparatus to the Analyzer

Use the following procedure to connect the GPT apparatus to the analyzer.

1. Assemble a dynamic calibration system such as the one shown in Figure 4–1.

2. Ensure that all flow meters are calibrated under the conditions of use against a reliable standard, such as a soap-bubble meter or wet-test meter. All volumetric flow rates should be corrected to 25 °C and 760 mmHg.

3. Precautions should be taken to remove O_2 and other contaminants from the NO pressure regulator and delivery system prior to the start of calibration to avoid any conversion of NO to NO_2. Failure to do so can cause significant errors in calibration. This problem can be minimized by:

   a. Carefully evacuating the regulator after the regulator has been connected to the cylinder and before opening the cylinder valve.

   b. Thoroughly flushing the regulator and delivery system with NO after opening the cylinder valve.

   c. Not removing the regulator from the cylinder between calibrations unless absolutely necessary.

4. Connect the analyzer sample bulkhead input to the output of the GPT system.

Adjust Instrument Gain

Use the following procedure to adjust the instrument gain. This includes:

- Setting the NO and NO_x background to zero
- Calibrating the NO channel to the NO calibration gas
- Calibrating the NO_x channel to the NO_x calibration gas

Set NO and NO_x Background to Zero

The NO and NO_x background corrections are determined during zero calibration. The background signal is the combination of electrical offsets, PMT dark current, and trace substances undergoing chemiluminescence. For more detailed information, see “Calibrate NO and NOx Background” in the “Operation” chapter.

Use the following procedure to set the NO and NOx backgrounds to zero. Both the NO and NO_x background screens operate the same way.

Note The NO channel should be calibrated first and then calibrate the NO_x channel. ▲

For detailed information about the menu parameters and the icons used in these procedures, see the "Operation" chapter.

1. Determine the GPT flow conditions required to meet the dynamic parameter specifications as indicated in "Dynamic Parameter Specifications for Gas Titrator" earlier in this chapter.

2. Adjust the GPT diluent air and O_3 generator air flows to obtain the flows determined in "Dynamic Parameter Specifications for Gas Titrator" earlier in this chapter. The total GPT airflow must exceed the total demand of the analyzer. The 42iQ requires approximately 700 cc/min of sample flow, and a total GPT airflow of at least 1.5 liters/min is recommended.

   a. Allow the analyzer to sample zero air until the NO, NO_2, and NO_x responses stabilize.

   b. After the responses have stabilized, from the Home Screen, choose **Calibration>Calibrate Backgrounds>Calibrate NO Background**.

      The Target NO Concentration button will read 0.00. The Calculated NO Background button will display the background needed to make the current NO concentration go to 0.00.

   c. Press **Calibrate** to set the NO reading to zero and to save the new background.

   d. Press the Back button to return to the Calibration Backgrounds screen and repeat this procedure to set the **Calibrate NOx Background** to zero.

   e. Record the stable zero air responses as Z_{NO}, Z_{NOX}, and Z_{NO2}.

3. Adjust the NO flow from the standard NO cylinder to generate a NO concentration of about 80% of the upper range limit (URL) of the NO range. The exact NO concentration is calculated from:

$$[NO]_{OUT} = \frac{F_{NO} \times NO_{STD}}{F_{NO} + F_O + F_D}$$

Where:

$[NO]_{OUT}$ = Diluted NO concentration at the output manifold, ppm

NO_{STD} = No feed concentration

F_{NO} = No flow

F_O = Ozone flow

F_D = Dilution flow

Calibrate the NO Channel to the NO Calibration Gas

Use the following procedure to calibrate the NO channel to the NO calibration gas.

1. Allow the analyzer to sample the NO calibration gas until the NO, NO_2, and NO_x readings have stabilized.

2. When the responses stabilize, from the Home Screen, choose **Calibration>Calibrate Span Coefficients>Calibrate NO Span Coefficient**.

   The user sets the span concentration by pressing the Edit NO Span Concentration button. The Calculated NO Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed. Pressing the Calibrate button will save the new NO span coefficient and calibrate the instrument.

3. Enter the NO calibration gas concentration using the pushbuttons, and then press **Calibrate** to calibrate the instrument to the NO calibration gas.

4. Record the $[NO]_{OUT}$ concentration and the instrument's response.

Calibrate the NO_x Channel to the NO_x Calibration Gas

Use the following procedure to calibrate the NO_x channel to the NO_x calibration gas.

1. Press the Back button to return to the Calibration menu, and choose **Calibrate NO_x Span Coefficient**.

2. Verify that the NO_x calibration gas concentration is the same as the NO calibration gas concentration plus any known NO_2 impurity.

   The user sets the span concentration by pressing the Edit NO_x Span Concentration button. The Calculated NO_x Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed. Pressing the Calibrate button will save the new NO_x span coefficient and calibrate the instrument.

3. Enter the NO_x calibration gas concentration using the pushbuttons, and then press **Calibrate** to calibrate the instrument to the NO_x calibration gas.

   The exact NO_x concentration is calculated from:

$$[NO_x]_{OUT} = \frac{F_{NO} \text{ x } ([NO]_{STD} + [NO_2]_{IMP})}{F_{NO} + F_O + F_D}$$

   Where:

   $[NO_x]_{OUT}$ = diluted NO_x concentration at the output manifold, ppm

   $[NO_2]_{IMP}$ = concentration of NO_2 impurity in the standard NO cylinder, ppm

4. Record the NO_x concentration and the analyzer's NO_x response.

Preparing NO, NO_x, and NO_2 Calibration Curves

Use the following procedures to prepare the NO, NO_x, and NO_2 calibration curves.

1. Generate several additional NO and NO_x concentrations by decreasing F_{NO} or increasing F_D.

2. For each concentration generated, calculate the exact NO and NO_x concentrations using the above equations for $[NO]_{OUT}$ and $[NO_x]_{OUT}$.

3. Record the NO and NO_x responses.

4. Plot the analyzer responses versus the respective calculated NO and NO_x concentrations and draw or calculate the respective calibration curves. For subsequent calibrations where linearity can be assumed, these curves may be checked with a three-point calibration consisting of a zero point, NO and NO_x concentrations of approximately 80% of the URL, and an intermediate concentration.

5. Adjust the GPT system to generate a NO concentration near 90% of the URL of the instrument range selected.

6. Sample this NO concentration until the NO and NO_x responses have stabilized, then measure and record the NO concentration as $[NO]_{ORIG}$.

7. Adjust the O_3 generator in the GPT system to generate sufficient O_3 to produce a decrease in the NO concentration equivalent to about 80% of the URL of the NO_2 range. The decrease must not exceed 90% of the NO concentration determined in Steps 5 and 6 above.

8. When the analyzer responses stabilize, record the resultant NO concentrations as $[NO]_{REM}$.

9. Press the Back button to return to the Calibration menu, and choose **Calibrate NO_2 Span Coefficient**.

   The user sets the span concentration by pressing the Edit NO_2 Span Concentration button. The Calculated NO_2 Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed. Pressing the Calibrate button will save the new NO_2 span coefficient and calibrate the instrument.

10. Enter the NO_2 calibration gas concentration using the pushbuttons, and then press **Calibrate** to concentration to reflect the sum of the following: the NO_2 concentration generated by GPT, ($[NO]_{ORIG}$ - $[NO]_{REM}$), and any NO_2 impurity.

    The exact NO_x concentration is calculated from:

$$[NO_2]_{OUT} = ([NO]_{ORIG} - [NO]_{REM}) + \frac{F_{NO} \times [NO_2]_{IMP}}{F_{NO} + F_O + F_D}$$

    Where:

    $[NO_2]_{OUT}$ = diluted NO_2 concentration at the output manifold, ppm

    $[NO]_{ORIG}$ = original NO concentration, prior to addition of O_3, ppm

    $[NO]_{REM}$ = NO concentration remaining after addition of O_3, ppm

    The analyzer does a one point NO_2 span coefficient calculation, corrects the NO_2 reading for converter inefficiency, and then adds the corrected NO_2 to the NO signal to give a corrected NO_x signal.

    If the analyzer calculates a NO_2 span coefficient of less than 0.96, either the entered NO_2 concentration is incorrect, the converter is not being heated to the proper temperature, the instrument needs servicing (leak or imbalance), or the converter needs replacement or servicing. The NO_2 analog output will reflect the NO_2 concentration generated by GPT, any NO_2 impurity, and the NO_2 zero offset.

11. Record the NO_2 concentration and the analyzer's NO_2 response.

12. Maintaining the same F_{NO}, F_O, and F_D, adjust the ozone generator to obtain several other concentrations of NO_2 over the NO_2 range (at least five evenly spaced points across the remaining scale are suggested).

13. Record the stable responses and plot the analyzer's NO_2 responses versus the corresponding calculated (using the above equation for $[NO_2]_{OUT}$) concentrations and draw or calculate the NO_2 calibration curve.

Note It is important that the curve be linear within ±1% FS over the NO_2 range. If the curve is nonlinear, the analyzer is not operating correctly, (possible leak, or converter failure, etc.), and should be serviced. Assuming the curve is linear, subsequent data should be reduced using this NO_2 calibration curve response. ▲

Note The user can also manually change the calibration factors. This is often useful in a troubleshooting situation. From the Home screen, choose Calibration>Advanced Calibration>Manual Calibration>**Adjust Span Coefficients**.

However, after the above calibration procedure is completed, all subsequent data reduction depends on the calibration parameters remaining the same as during the initial calibration. Therefore, never change any calibration factor without first recording the value so that after any troubleshooting procedure is completed, the initial value can be re-entered thereby not altering the multipoint calibration. ▲

Alternative Calibration Procedure Using NO_2 Permeation Tube

Although it is recommended that a GPT system be used to calibrate the analyzer, the procedure described in the Code of Federal Regulations, Title 40, Part 50, Appendix F using a NO_2 permeation tube may be used as an alternative procedure for calibrating the instrument.

Commercial Precision Dilution Systems

Commercial precision dilution systems are available which reliably and accurately dilute a high concentration gas mixture to provide a reliable span gas. A high concentration of NO_2 in air is precisely diluted to the concentration range required.

The Thermo Scientific 146iQ Multi-gas Calibrator is one such system for precision dilution.

Permeation Tube System

Permeation tube systems which precisely maintain a set temperature to within ±0.1 °C and hold a zero air flow rate to within ±0.5% can be used for generation of span gas. The flow rate of the permeation system must be at least 0.5 LPM for proper operation.

A permeation tube system, shown in Figure 4–2 can be constructed. All connections between components in the system should be made with glass, PTFE, or other non-reactive material.

The air flow controllers should be capable of maintaining a constant air flow within ±2% of the required flow rate. Ensure all devices are properly calibrated and that all flows are corrected to 25 °C and 1 atm.

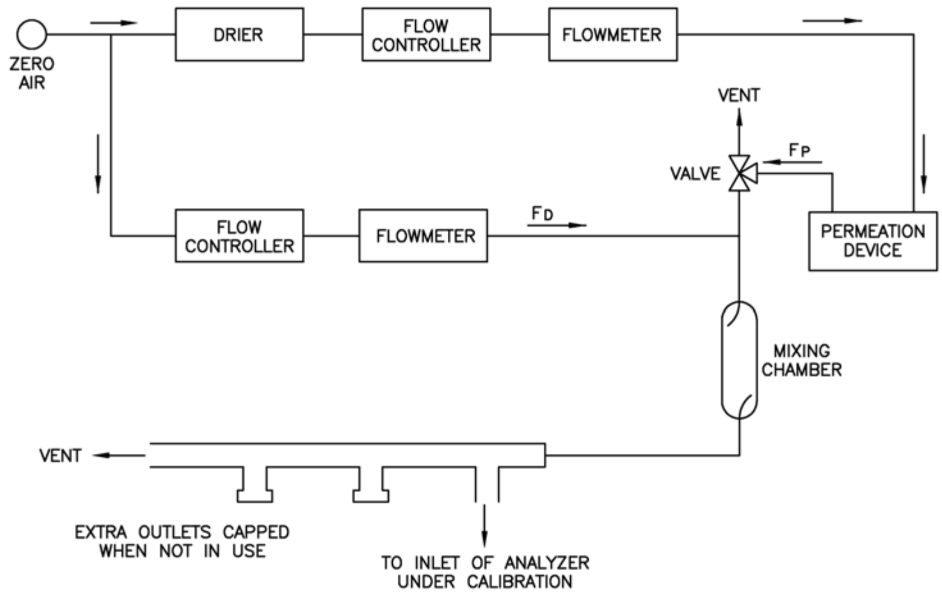


Figure 4–2. Permeation Tube System

The NO_2 output level is calculated from:

$$[NO_2]_{OUT} = \frac{P \times K}{F_T}$$

Where:

$[NO_2]_{OUT}$ = NO_2 output concentration in ppm

P = permeation rate in µg/min

F_T = total flow rate of gas after mixing chamber (F_P + F_D) in liters/minute

K (NO_2) = 0.382 constant for NO_2 permeant

Commercial Permeation Systems

Commercial permeation systems, such as the Thermo Scientific 146iQ Multigas Calibration System, are available for this requirement. Refer to the instrument instruction manual for more information.

In addition to the 146iQ and other commercial permeation systems, the 42iQ can also be configured with an optional permeation oven to supply calibration gas for the instrument. The operation of the internal permeation oven is described in Chapter 9, "Optional Equipment".

Calibration in Dual Range and Auto Range Mode

The dual/auto range calibration feature is used to calibrate the analyzer at two different span levels (as opposed to a single span level in the standard mode) generating a "tailored multi-point" calibration curve stored in the analyzer's memory. This feature may be used:

- When widely different gas levels are being monitored, such as a factor of 10 or greater apart
- If precision and span levels are being introduced using separate tanks
- If more than one multi-component cylinder is being used to calibrate the instrument

Properly designed chemiluminescence analyzers are inherently linear over a wide dynamic range; and under normal U.S. EPA compliance situations this feature is not required. Dual calibration may be used for span levels less than a factor of 10 apart, however if this is done to correct for a significant non-linearity, it may mask the problems causing the effect, such as, bad calibration cylinder, leaks in sampling lines, or low ozonator output.

Set NO and NO_x Backgrounds to Zero

Use the following procedure to set the NO and NO_x backgrounds to zero. Both the NO and NO_x background screens operate the same way.

Note The NO channel should be calibrated first and then calibrate the NO_x channel. ▲

For detailed information about the menu parameters and the icons used in these procedures, see the "Operation" chapter.

1. Follow the "Pre-Calibration" procedure described previously in this chapter.

2. Be sure the instrument is in the auto or dual mode. If the instrument is not in auto or dual mode:

   a. From the Home screen choose **Settings>Measurement Settings>Range Mode Selection**.

   b. Select **Auto** or **Dual** mode.

3. Introduce zero air to the SAMPLE bulkhead and allow the analyzer to sample zero air until the NO, NO_2, and NO_x responses stabilize.

4. After the responses have stabilized, from the Home Screen, choose **Calibration>Calibrate Backgrounds>Calibrate NO Background**.

   The Target NO Concentration button will read 0.000. The Calculated NO Background button will display the background needed to make the current NO concentration go to 0.000.

5. In the Calibrate Backgrounds screen, press **Calibrate** to set the NO reading to zero and to save the new background.

6. Press the Back button to return to the Calibration Backgrounds screen and repeat this procedure to set the **Calibrate NO_x Background** to zero.

Calibrate NO Low

Use the following procedure to calibrate NO channel to the NO calibration gas.

1. Disconnect the source of zero air from the SAMPLE bulkhead. In its place, connect a source of NO calibration gas of about 80% of the low NO full-scale range.

2. Allow the analyzer to sample the low NO calibration gas until the NO, NO_2, and NO_x readings stabilize.

3. When the responses stabilize, from the Home screen, choose **Calibration>Calibrate Span Coefficients>Calibrate Low Range NO Span Coefficient**.

   The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated Low Range NO Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

4. Enter the NO calibration gas concentration using the pushbuttons, and then press **Calibrate** to calculate and save the new low range NO span coefficient based on the entered span coefficient.

Calibrate NO_x Low

Use the following procedure to calibrate the NO_x channel to the NO_x calibration gas.

1. Press the Back button to return to the Calibration menu and choose **Calibrate Low Range NO_x Span Coefficient**.

   The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated Low Range NO_x Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

2. Verify that the low NO_x calibration gas concentration is the same as the low NO calibration gas concentration plus any known NO_2 impurity.

3. Enter the NO_x calibration gas concentration using the pushbuttons, and then press **Calibrate** to calculate and save the new low range NO_x span coefficient based on the entered span coefficient.

Calibrate NO_2 Low

Use the following procedure to calibrate the NO_2 channel to the NO_2 calibration gas.

1. Adjust the O_3 generator in the GPT system to generate sufficient O_3 to produce a decrease in the low NO concentration equivalent to about 80% of the URL of the low NO_2 range. The decrease must not exceed 90% of the low NO concentration determined in the "Calibrate NOx Low" procedure.

2. Press the Back button to return to the Calibration menu and choose **Calibrate Low Range NO_2 Span Coefficient**.

The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated Low Range NO_2 Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

3. Set the low NO_2 calibration gas concentration to reflect the sum of the NO_2 concentration generated by GPT and any NO_2 impurity using the pushbuttons, and then press **Calibrate** to calculate and save the new low range NO_2 span coefficient based on the entered span coefficient.

Calibrate NO High

Use the following procedure to calibrate the NO channel to the NO calibration gas.

1. Connect a source of high NO calibration gas of about 80% of the high NO full-scale range. Allow the analyzer to sample the high NO calibration gas until the NO, NO_2, and NO_x readings have stabilized.

2. After the responses stabilize, from the Home screen, choose **Calibration>Calibrate Span Coefficients>Calibrate High Range NO Span Coefficient**.

   The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated High Range NO Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

3. Enter the NO calibration gas concentration using the pushbuttons, and then press **Calibrate** to calculate and save the new high range NO span coefficient based on the entered span coefficient.

Calibrate NO_x High

Use the following procedure to calibrate the NO_x channel to the NO_x calibration gas.

1. Press the Back button to return to the Calibration menu and choose **Calibrate High Range NO_x Span Coefficient**.

   The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated High Range NO_x Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

2. Verify that the high NO_x calibration gas concentration is the same as the low NO calibration gas concentration plus any known NO_2 impurity.

3. Enter the NO_x calibration gas concentration using the pushbuttons, and then press **Calibrate** to calculate and save the new high range NO_x span coefficient based on the entered span coefficient.

Calibrate NO_2 High

Use the following procedure to calibrate the NO_2 channel to the NO_2 calibration gas.

1. Adjust the O_3 generator in the GPT system to generate sufficient O_3 to produce a decrease in the high NO concentration equivalent to about 80% of the URL of the high NO_2 range. The decrease must not exceed 90% of the high NO concentration determined in the "Calibrate NOx High" procedure.

2. Press the Back button to return to the Calibration menu and choose **Calibrate High Range NO_2 Span Coefficient**.

   The user sets the span concentration by pressing the Edit Span Concentration button. The Calculated High Range NO_2 Span Coefficient button will show what the span coefficient will be set to if the Calibrate button is pressed.

3. Set the high NO_2 calibration gas concentration to reflect the sum of the NO_2 concentration generated by GPT and any NO_2 impurity using the pushbuttons, and then press **Calibrate** to calculate and save the new high range NO_2 span coefficient based on the entered span coefficient.

Zero and Span Check

The analyzer requires initial and periodic calibration according to the procedures outlined in this manual. Initially, the frequency of the calibration procedure should be determined by the stability of the zero and span checks, which may be run daily. You should generate a new calibration curve when zero and span checks indicate a shift in instrument gain of more than 10 percent from that determined during the most recent multipoint calibration. You can adjust the frequency of calibration and even zero and span checks appropriately as you gain confidence with the instrument.

It is recommended to have a quality control plan where the frequency and the number of points required for calibration can be modified on the basis of calibration and zero and span check data collected over a period of time.

Note however, that the EPA requires a minimum of one multipoint calibration per calendar quarter. Such a quality control program is essential to ascertain the accuracy and reliability of the air quality data collected and to alert the user if the accuracy or reliability of the data should become unacceptable. A compilation of this kind might include items such as dates of calibration, atmospheric conditions, calibration factors, and other pertinent data.

Use the following procedure to perform a zero and span check.

1. Connect the zero gas to the SAMPLE bulkhead in a standard instrument or to the ZERO IN bulkhead in a 42iQ equipped with the zero/span and sample solenoid valve option.

2. Allow the instrument to sample zero gas until a stable reading is obtained on the NO, NO_2, and NO_x channels then record the zero readings. Unless the zero has changed by more than ±0.010 ppm, it is recommended that the zero not be adjusted. If an adjustment larger than this is indicated due to a change in zero reading, a new multipoint calibration curve should be generated.

3. Attach a supply of known concentration of NO and NO_2 (usually generated via an NIST traceable NO working standard and a GPT system) to the SAMPLE bulkhead (or SPAN bulkhead for instruments equipped with the zero/span and sample solenoid valve option) on the rear panel.

4. Allow the instrument to sample the calibration gas until a stable reading is obtained on the NO, NO_2, and NO_x channels. If the calibration has changed by more than ±10%, a new multipoint calibration curve should be generated.

5. When the calibration check has been completed, record the NO, NO_2, and NO_x values.

6. Reconnect the analyzer sample line to the SAMPLE bulkhead.

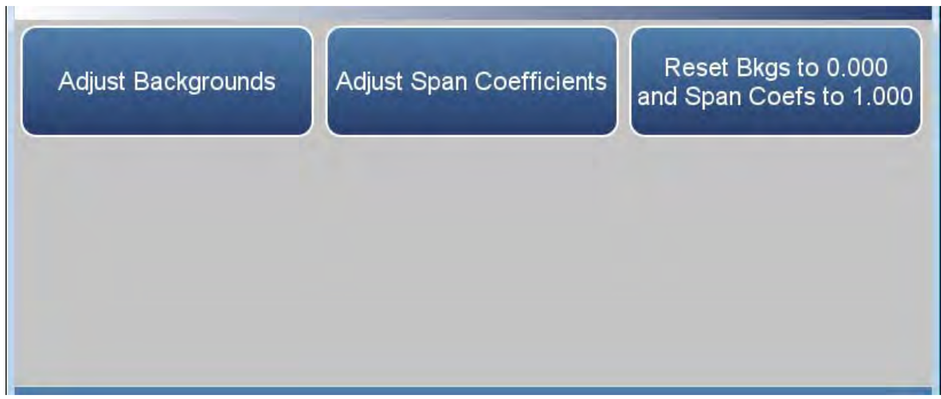
Manual Calibration

The Manual Calibration screen allows the user to view and manually adjust the zero background and span coefficient. These are used to correct the NO, NO_2, and NO_x readings that the instrument generates using its own internal calibration data.

Normally, the zero background and span coefficient are calculated automatically at the Calibrate Background and Calibrate Span Coefficient described earlier in the chapter. However, the calibration factors can also be set manually using the functions as described below.

The following screen is shown in single range mode. In dual or auto range modes, “High Range” or “Low Range” buttons are displayed to indicate the calibration of the high or low coefficient. The Adjust High Range Span Coefficient and Adjust Low Range Span Coefficient screens function the same way.

Home Screen>Calibration>Advanced Calibration>Manual Calibration



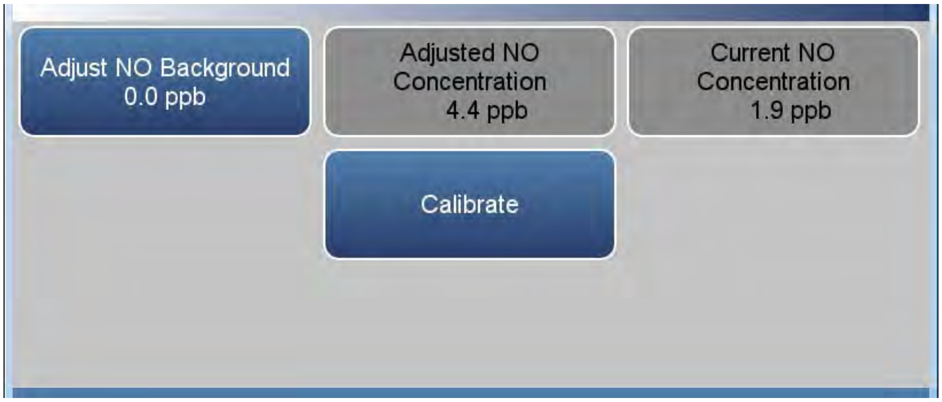
Adjust NO and NO_x Backgrounds

The NO background is the amount of signal read by the analyzer in the NO channel while sampling zero air. The NO_x background is the amount of signal read by the analyzer in the NO_x channel while sampling zero air.

The Adjust Background screens are used to perform a manual zero background calibration of the instrument. As such, the instrument should sample zero air until stable readings are obtained. The NO channel should be calibrated first. Both the NO and NO_x Adjust Background screens operate the same way.

The button labeled Adjust NO Background allows the user to change zero background. The second button called Adjusted NO Concentration shows what the new NO concentration would be based on the changed zero background. Press the Calibrate button to save the adjusted zero background value.

Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Backgrounds>Adjust NO Background



Adjust Span Coefficient

The span coefficients are used to correct the NO, NO_2, and NO_x readings. The NO and NO_x span coefficient normally has a value near 1.000. The NO_2 span coefficient normally has a value between 0.95 and 1.050.

The user can manually change the span coefficient by entering a value in the Adjust Span Coefficient button. The second button called Adjusted Concentration shows what the new concentration would be based on the adjusted span coefficient. Press the Calibrate button to save the adjusted span coefficient value. The NO, NO_2, and NO_x coefficient screens operate the same way.

Home Screen>Calibration>Advanced Calibration>Manual Calibration>Adjust Span Coefficients>Adjust NO Span Coefficient (single range mode)

Home Screen> Calibration>Advanced Calibration>Manual Calibration>Adjust Coefficients> Adjust High Range NO Span Coefficient (dual or auto range mode)

Reset Bkg to 0.000 and Span Coef to 1.000

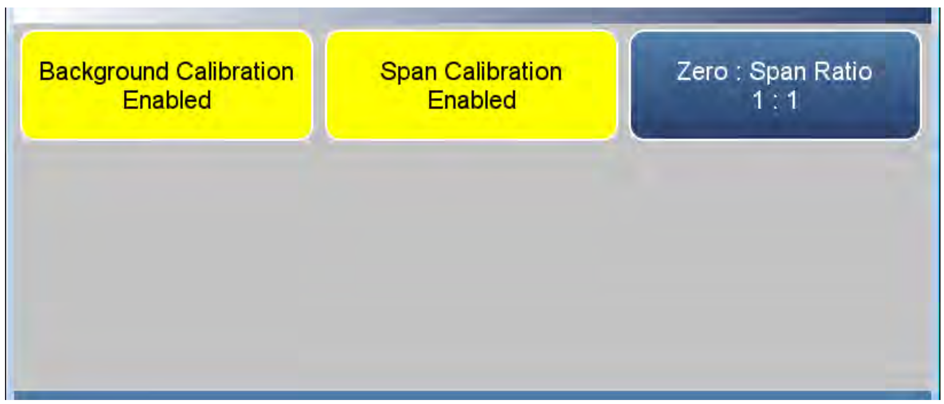
The Reset Bkg to 0.000 and Span Coef to 1.000 screen allows the user to reset the calibration configuration values to factory defaults.

Zero/Span Schedule

The Zero/Span Schedule screen is available only if the zero/span valve option is installed and turned on (toggles enabled or disabled) at the screen Settings>Configuration. It is used to program the instrument to perform fully automated zero and span calibration or calibration checks.

Home Screen>Calibration>Zero/Span Schedule

Home Screen>Calibration>Zero/Span Schedule>More



Next Time

The Next Time button is used to view and set the initial date and time (24-hour format) of the zero/span schedule. Once the zero/span schedule begins, the date and time of the next zero/span schedule is calculated and displayed.

Period

The Period button defines the period or interval between zero/span schedule. Periods between 0 and 999 hours are acceptable. To turn the zero/span schedule off, set the period to 0.

Zero/Span/Purge Duration Minutes

The Zero Duration button defines how long zero air is sampled by the instrument. The Span and Purge Duration buttons look and function the same way as the zero duration button. The span duration button is used to set how long the span gas is sampled by the instrument. The purge duration button is used to set how long the purge period will be after doing a zero and/or span. This gives the instrument time to flush out the zero and span gas before any meaningful sample data is taken. Logged data is flagged as taken during a purge to show that the data is suspect. Durations between 0 and 99 minutes are acceptable. Each time a zero/span schedule occurs the zero is done first, followed by the span. To perform just a zero, set the span duration to 0 (off). The same applies to perform just a span.

Schedule Averaging Time

The Schedule Averaging Time button allows the user to adjust the schedule averaging time. The schedule averaging time is used by the analyzer only when performing a zero/span schedule. The analyzer's averaging time is used for all other functions. Range is 1–300 seconds.

Background Calibration and Span Calibration

Background Calibration and Span Calibration are toggle buttons that change between enabled or disabled.

If the background calibration is set to enabled, then a zero adjustment is made. If the span calibration is set to enabled, then a span adjustment is made. (This is how to set up a scheduled, recurring auto calibration.)

Zero/Span Ratio

The Zero/Span Ratio button is used to set the ratio of zero checks or adjustments to span checks or adjustments. For example, if this value is set to 1, a span duration will follow every zero duration. If this value is set to 3, there will be two zero checks between each span check. This value may be set from 1 to 99, with 1 as default.

References

1. Section 12 of EPA *Quality Assurance Handbook for Air Pollution Measurement Systems*, Volume II, available at www.epa.gov.

   Section 12 also provides information on "Calibration of Primary and Secondary Standards for Flow Measurements".

   Specific information on certification of concentration standards is given in EPA *Traceability Protocol for Assay and Certification of Gaseous Calibration Standards*, available at www.epa.gov.

Chapter 5
Maintenance

This chapter describes the periodic maintenance procedures that should be performed on the instrument to ensure proper operation. Since usage and environmental conditions vary greatly, you should inspect the components frequently until an appropriate maintenance schedule is determined.

Safety Precautions

Read the safety precautions before beginning any procedures in this chapter.

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. For more information about appropriate safety precautions, see the "Servicing" chapter. ▲

Fan Filter Inspection and Cleaning

Use the following procedure to inspect and clean the fan filter.

1. Remove the fan guard from the fan and remove the filter. Refer to Filter Replacement on page 7-6.

2. Flush the filter with warm water and let dry (a clean, oil-free purge will help the drying process) or blow the filter clean with compressed air.

3. Re-install the filter and fan guard.

Thermoelectric Cooler Fins Inspection and Cleaning

Use the following procedure to inspect and clean the thermoelectric cooler fins.

1. Turn the instrument OFF and unplug the power cord.

2. Remove the PMT cooler from the instrument. Refer to “PMT Cooler Shroud Removal” on page 7-30.

3. Blow off the cooler fins using clean pressurized air. It may be more convenient to vacuum the cooler fins. In either case, make sure that particulate accumulation between the fins has been removed.

4. In necessary, use a small brush to remove residual particulate accumulation.

Capillaries Inspection and Replacement

The capillaries normally only require inspection when instrument performance indicates that there may be a flow problem.

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly ground antistatic wrist strap must be worn while handling any internal component. ▲

Use the following procedure to inspect and replace the capillaries. This procedure can be used to check any or all of the capillaries.

1. Turn instrument OFF, unplug power cord and remove the cover (Figure 2–1).

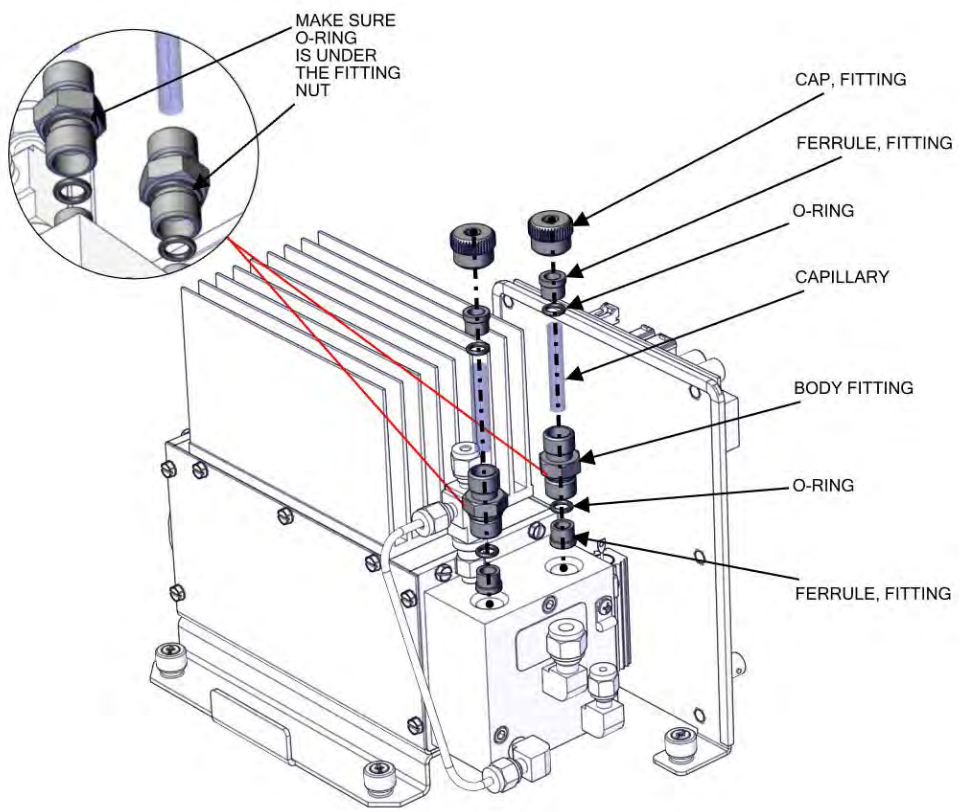


Figure 5–1. Inspecting and Replacing the Capillaries

2. Remove the fitting(s) from the reaction chamber body using a 5/8-inch wrench being careful not to lose the ferrule or o-ring.

3. Remove the glass capillaries, ferrule, and o-ring. Inspect o-ring for cuts or abrasion, and replace as necessary.

4. Check capillary for particulate deposits. Clean or replace as necessary.

5. Replace capillary in reaction chamber body, making sure the o-ring is around the capillary before inserting it into the body.

6. Replace fitting. Note that the fitting should be tightened slightly more than hand tight.

7. Reconnect tubing to top of fittings, being careful to insert ferrule and o-ring properly, and tighten knurled nut finger tight.

8. Re-install the cover.

9. Connect the power cord and turn the instrument ON.

Pump Rebuilding

Use the following procedure to rebuild the pump.

Equipment required:

Pump rebuild kit (qty. 2)

Phillips drive, #1 or Torque drive, T10 (depending on pump version)

Pencil or marker

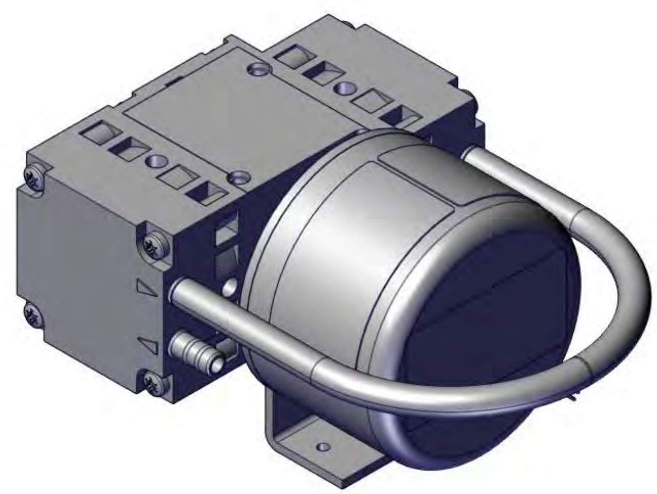


Figure 5–2. Dual Stage Pump

Note To avoid opening the pneumatic connection between the pump heads, service the pump as described below with the following addition: Make steps 1 to 3 and 11 for both pump heads together. ▲

1. Turn instrument OFF, unplug the power cord, and remove the cover.

2. Mark the position of head parts relative to each other by drawing a line with a pencil. This helps avoid incorrect assembly later.

3. Undo the four screws in the head.

4. Lift the head plate and the intermediate plate off the housing.

5. Hold the pump with one hand, so that the diaphragm is pointing downwards. Lift the diaphragm by the opposing side edges, grasp it and unscrew it in the counter-clockwise direction.

6. Remove connection rod disc and diaphragm spacers from the threaded pin of the diaphragm.

7. Push the connection rod disc and the diaphragm spacers in this order onto the threaded pin of the new diaphragm.

8. Move the connecting rod to the upper point.

9. Screw the new diaphragm with connection rod disc and spacers clockwise onto the connection rod and tighten hand-tight.

10. Place the intermediate plate on housing, in the position indicated by the drawing line.

11. Place the new valve plate on the intermediate plate.

12. Place the head plate on the intermediate plate, in the position indicated by the drawing line; gently tighten the four screws, evenly and diagonally (if a torque screwdriver is available: torque about 0.30 Nm).

13. Let the pump run.

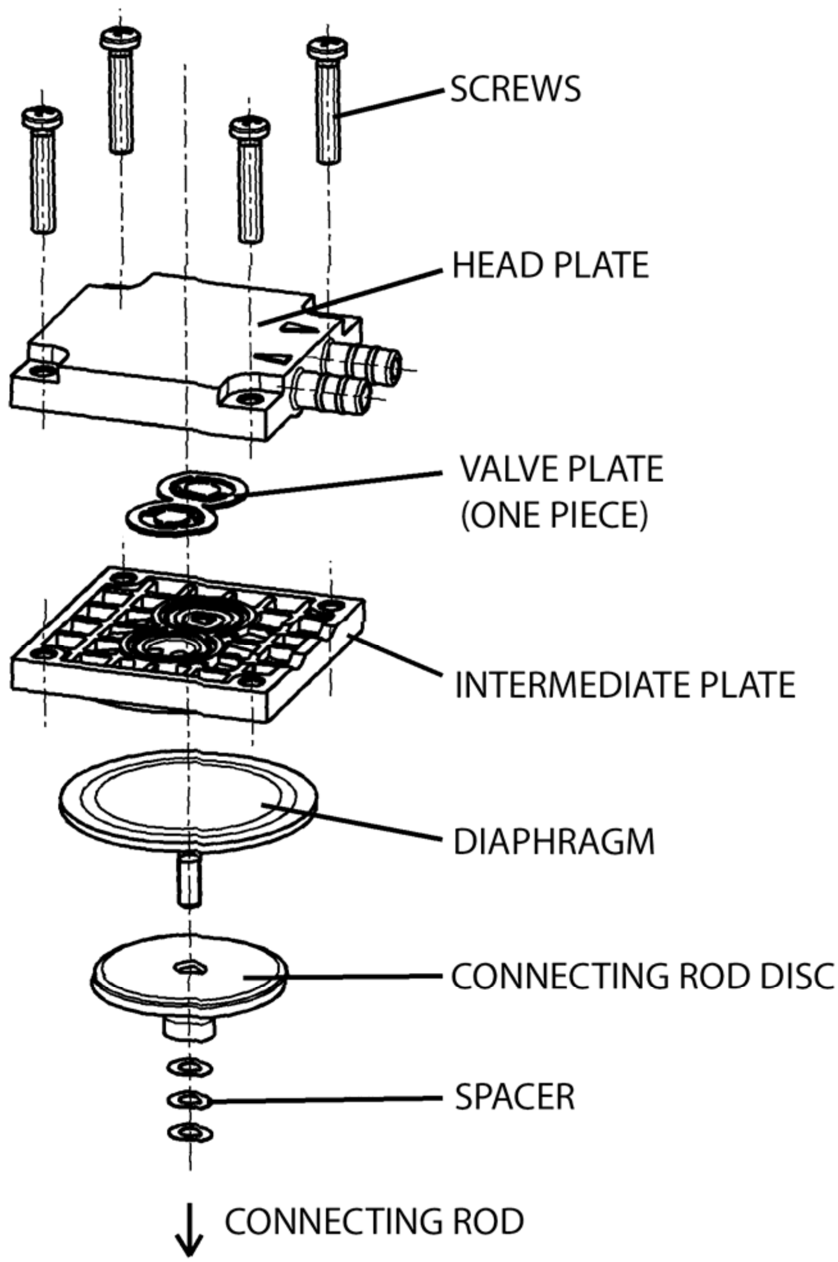


Figure 5–3. Pump Rebuilding

Leak Test

Use the following procedure to perform a leak test.

Equipment Required:

Cap

Vacuum Tester with Gauge (with a resolution of .5 in Hg or better)

1. Turn instrument OFF, unplug the power cord.

2. Block the SAMPLE bulkhead on the rear panel with a leak-tight cap.

3. Connect the vacuum tester tool to the EXHAUST bulkhead on the rear panel.

4. Squeeze trigger until gauge reads to pull in 10 in Hg.

5. Observe vacuum gauge for stable reading for 5 minutes. If reading remains at 10 in Hg, no leak is present.

Note Acceptable leak rate is .5 in Hg over 10 minutes. ▲

Chapter 6
Troubleshooting

The troubleshooting guide presented in this chapter is designed to help isolate and identify instrument problems.

Safety Precautions

Read the safety precautions in Appendix A, "Safety" before performing any actions listed in this chapter.

Troubleshooting Guide

Table 6–1 provides general troubleshooting information for the common platform and indicates the checks that you should perform if you experience an instrument problem. It also lists 42iQ specific troubleshooting information and alarm messages you may see on the graphics display and provides recommendations about how to resolve the alarm condition.

Table 6–1. 42iQ Troubleshooting Guide

Problem	Possible Cause	Action
Instrument does not start (LEDs on front panel do not come on and display is blank)	No power	Verify that the power cord is plugged in, power is available and that it matches the voltage and frequency configuration of the instrument.
	Fuse is blown or missing	Disconnect power and check fuses with a volt meter.
	Bad switch or wiring connection to switch	Check for 24V @ J9 on the Backplane board (middle pins). Check all wiring connections.
Front panel display does not start (LEDs on front panel are off)	Disconnected ribbon cable	Power down and evaluate connections of display ribbon cable.
Front panel display does not start (LEDs on front panel are on)	Defective Display	Connect to the instrument using ePort. Select "Remote Interface". If normal GUI is displayed, replace defective display.
Front panel display stays white after power up (LEDs on front panel are on)	Unseated or missing Micro SD card	Power off, re-seat Micro SD or install if missing.

Problem	Possible Cause	Action
	Micro SD Card Programming	If Micro SD card was just replaced, re-install the old one. If the problem is fixed, request a replacement Micro SD card.
Solenoid current out of range (option)	Sticking or damaged solenoid	Reset solenoid via Settings>Health Check>Status and Alarms>Valve and Pump Resets screen. If damaged, replace solenoid valve block.
Pump current out of range	Damaged or dirty pump	Reset pump via Settings>Health Check>Status and Alarms>Valve and Pump Resets. Inspect and refurbish pump. If pump motor is damaged, replace pump.
No output signal (or very low output)	No sample gas reaching the analyzer	Check input sample flow.
	Ruptured pump diaphragm	Rebuild pump head.
	Blocked sample capillary	Unplug power cord. Clean or replace capillary.
	No ozone reaching the reaction chamber	Check the “Configuration” menu to see if the ozonator is ON. If it is ON, check dry air supply.
No output signal	Disconnected or defective input or high voltage supply	Unplug power cord. Check that cables are connected properly. Check cable resistance.
	Analyzer not calibrated	Recalibrate.
	Defective ±12 volt	Check supply voltages in Status and Alarms>Reaction Chamber screen
Calibration drift	Dryer to ozonator depleted	Replace.
	Line voltage fluctuations	Check to see if line voltage is within specifications.
	Defective pump	Rebuild pump.
	Unstable NO or NO_2 source	Replace.
	Clogged capillaries	Unplug power cord. Clean or replace capillary.
	Clogged sample air filter	Replace filter element.
Excessive noise	Defective or low sensitivity PMT	Unplug power cord. Remove PMT. Install known good PMT. Plug in power cord. Check performance.

Problem	Possible Cause	Action
	Defective cooler	Check temperature (less than -2 °C at T_{amb} = 25 °C).
Non-linear response	Incorrect calibration source	Verify accuracy of multipoint calibration source gas.
	Leak in sample probe line	Check for variable dilution.
Excessive response time	Partially blocked sample capillary	Unplug power cord. Clean or replace capillary.
	Hang up/blockage in sample filter	Change element.
Improper converter operation	Questionable calibration gas	Verify accuracy.
	Converter temperature too high or too low	Temperature should be approximately 325 °C for Molybdenum, 625 °C for stainless steel.
	Low line voltage	Check to see if line voltage is within specifications.
	Molybdenum consumed	Replace Molybdenum converter cartridge.
Alarm – Internal Temperature	Fan failure	Replace fan if not operating properly.
	Dirty fan filter	Clean or replace filter.
	Overheating PCB	Locate defective PCB reporting the error and replace if needed.
Alarm – Bench Temperature	Heaters failed	Replace heaters as needed.
	Defective PCB	Replace PCB.
Alarm – Cooler Temp Sensor	Check fan operation	Replace defective fan.
	Check fan filter	Clean or replace filter.
	Bad thermistor	Replace thermistor.
Alarm – NO_2 Converter Temperature	Converter temperature low	Molybdenum converter should be hot to the touch. If not, the heater may have failed. Check that converter temperature set point is approximately 325 °C.
Alarm – Perm Gas Temp	Incorrect Perm oven set temperature or alarm setting	Check that the alarm settings match the set temperature.
	Perm oven heater thermistor or gas thermistor error	Replace thermistor.

Problem	Possible Cause	Action
	Perm oven failure	Replace the Perm oven.
Alarm – Pressure	High pressure indication	Check plumbing for leaks.
		Check the pump for a tear in the diaphragm.
		Replace if needed.
		Check the capillary is properly installed and o-rings are in good shape.
Alarm – Flow	Flow low	Check sample capillary for blockage. Replace as necessary.
		If using sample particulate filter, make sure it is not blocked. Disconnect sample particulate filter from the sample bulkhead. If flow increases, replace the filter.
	Flow high	When delivering zero air or gas to the instrument, use an atmospheric dump.
	Flow = 0 LPM	Check that Step POL board #1 has both dip switch settings of SW2 off (both facing the rear of the instrument). Verify the pump is plugged into the Step POL board.
	Worn Diaphragm	Rebuild pump every 12 months or as needed.
Alarm – Ozonator Flow	Ozone flow low	Check ozone capillary for blockage. Replace as necessary.
Alarm – NO, NO_2, NO_x Concentration	Concentration has exceeded range limit	Check to ensure range corresponds with expected value. If not, select proper range.
		Check user-defined low set point; set to zero.
Alarm – Board Communication	Cable connection	Check that DMC cable is connected properly. Reseat if needed.
	Defective DMC PCB	Replace DMC board.
Alarm – Power Supply	Cable connection	Check that DMC cable is connected properly. Reseat if needed.
	Defective component	Check for other alarms, as it is possible that another component of that DMC is drawing too much current.
	Defective DMC PCB	Replace DMC board.

Problem	Possible Cause	Action
Alarm – Module Temperature	Cable connection	Check that DMC cable is connected properly. Reseat if needed.
	Other alarm	Make sure the instrument temperature is not too high or in alarm.
	Defective DMC PCB	Replace DMC board.
Alarm – 5V/24V Step Board	Cable connection	Check the cable connections to that Step POL board.
Alarm – Analog I/O	Defective PCB	Replace Analog board.
Alarm – Digital I/O	Defective PCB	Replace Digital board.
Alarm – NO Bkg Check Offset	Incorrect high alarm limit	Verify the high limit is correct via Settings>Status and Alarms>Concentrations screen.
	Instrument background calibration failed	Recalibrate the instrument.
Alarm – NO Span Check Offset	Incorrect high alarm limit	Verify the high limit is correct via Settings>Status and Alarms>Concentrations screen.
	Instrument span calibration failed	Recalibrate the instrument.
Alarm – Ambient Thermistor	Defective Flow/Pressure board	Replace defective DMC board as needed.
Alarm – Chamber Pressure	Defective Flow/Pressure board	Replace defective DMC board as needed.
Alarm – Bench Temperature Short	Cable connection	Check the cable connection from the heater to the DMC board.
	Broken wire	Verify the wires are properly connected to both sides of the heater.
	Defective heater	Replace heater as needed.
	Defective DMC board	Replace defective DMC board as needed.
Alarm – Bench Temperature Open	Cable connection	Check the cable connection from the heater to the DMC board.
	Broken wire	Verify the wires are properly connected to both sides of the heater.
	Defective heater	Replace heater as needed.
	Defective DMC board	Replace defective DMC board as needed.
Alarm – Cooler Current too Low	Defective cooler	Replace cooler as needed.

Problem	Possible Cause	Action
	Defective DMC board	Replace DMC board as needed.
Alarm – Cooler Current too High	Defective cooler	Replace cooler as needed.
	Defective DMC board	Replace DMC board as needed.
Alarm – Cooler Voltage too Low	Defective cooler	Replace cooler as needed.
	Defective DMC board	Replace DMC board as needed.
Alarm – Cooler Voltage too High	Defective cooler	Replace cooler as needed.
	Defective DMC board	Replace DMC board as needed.
Alarm – PMT Voltage too Low	Defective PMT	Replace PMT as needed.
	Defective DMC board	Replace DMC board as needed.
Alarm – PMT Voltage too High	Defective PMT	Replace PMT as needed.
	Defective DMC board	Replace DMC board as needed.
Alarm – Frequency too Low	Input board is out of calibration	Recalibrate the Input board.
Alarm – Frequency too High	Input board is out of calibration	Recalibrate the Input board.

Chapter 7
Servicing

This chapter describes the periodic servicing procedures that should be performed on the instrument to ensure proper operation and explains how to replace the 42iQ subassemblies.

Safety Precautions

Read the safety precautions before beginning any procedures in this chapter.

WARNING The service procedures in this manual are restricted to qualified service representatives. ▲

WARNING If the equipment is operated in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. ▲

CAUTION **CAUTION** If the LCD panel breaks, do not let the liquid crystal contact your skin or clothes. If the liquid crystal contacts your skin or clothes, wash immediately using soap and water. ▲

Do not remove the LCD panel or frame from the LCD module. ▲

The LCD polarizing plate is very fragile, handle it carefully. ▲

Do not wipe the LCD polarizing plate with a dry cloth, as it may easily scratch the plate. ▲

Do not use alcohol, acetone, MEK or other Ketone based or aromatic solvents to clean the LCD module, but rather use a soft cloth moistened with a naphtha cleaning solvent. ▲

Do not place the LCD module near organic solvents or corrosive gases. ▲

Do not shake or jolt the LCD module. ▲

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. For more information about appropriate safety precautions, see "Safety". ▲

Note If an antistatic wrist strap is not available, be sure to touch the instrument chassis before touching any internal components. When the instrument is unplugged, the chassis is not at earth ground. ▲

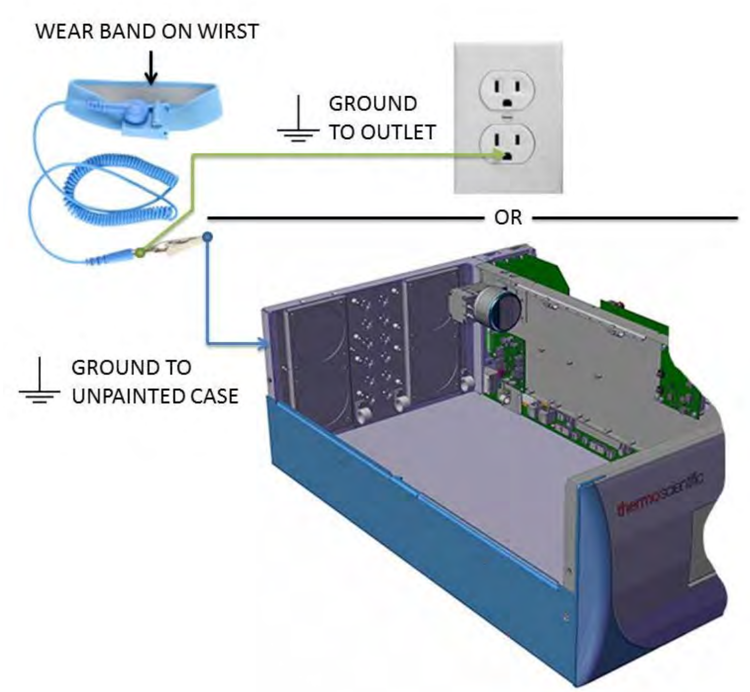


Figure 7–1. Properly Grounded Antistatic Wrist Strap

Note Ground to unpainted case or outlet as shown. ▲

Firmware Updates

New versions of the instrument software are periodically made available over Ethernet, USB flash drive, or company website at:

www.thermofisher.com

For more information on installing new firmware, see "Installing New Firmware" in the *iQ Series Communications* manual.

Replacement Parts List

For a complete list of spare parts, visit the company website at:

www.thermofisher.com/42iQ

Refer to Figure 7–2 and Figure 7–3 to identify the component location.

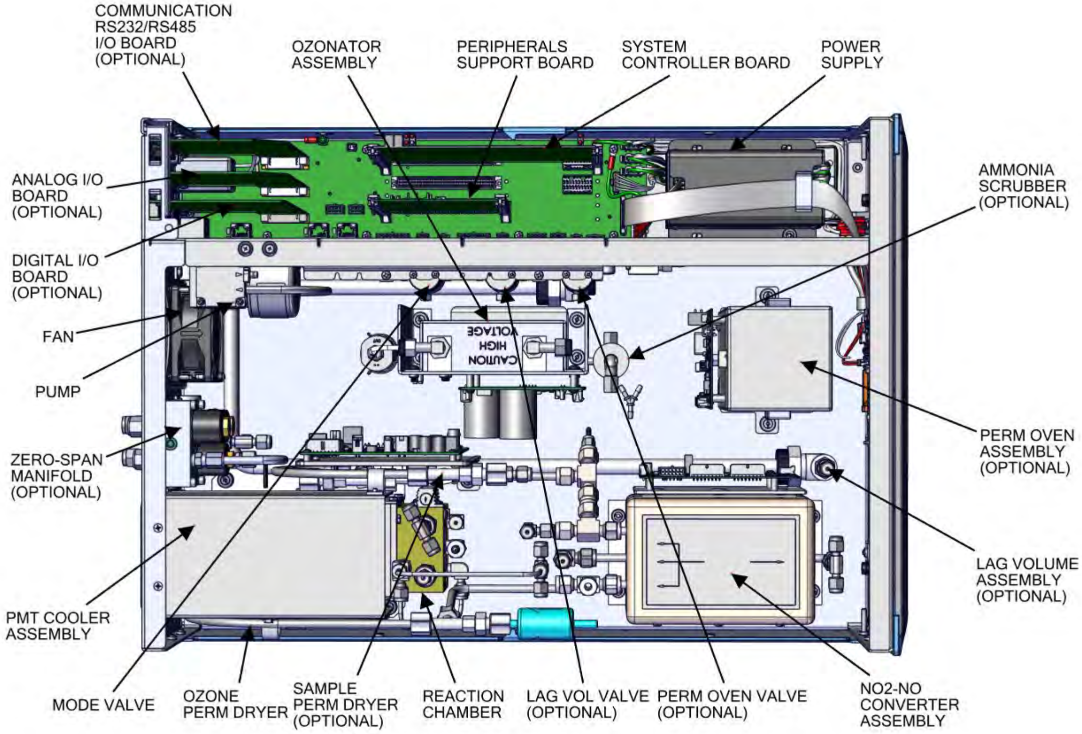


Figure 7–2. 42iQ Component Layout Top View

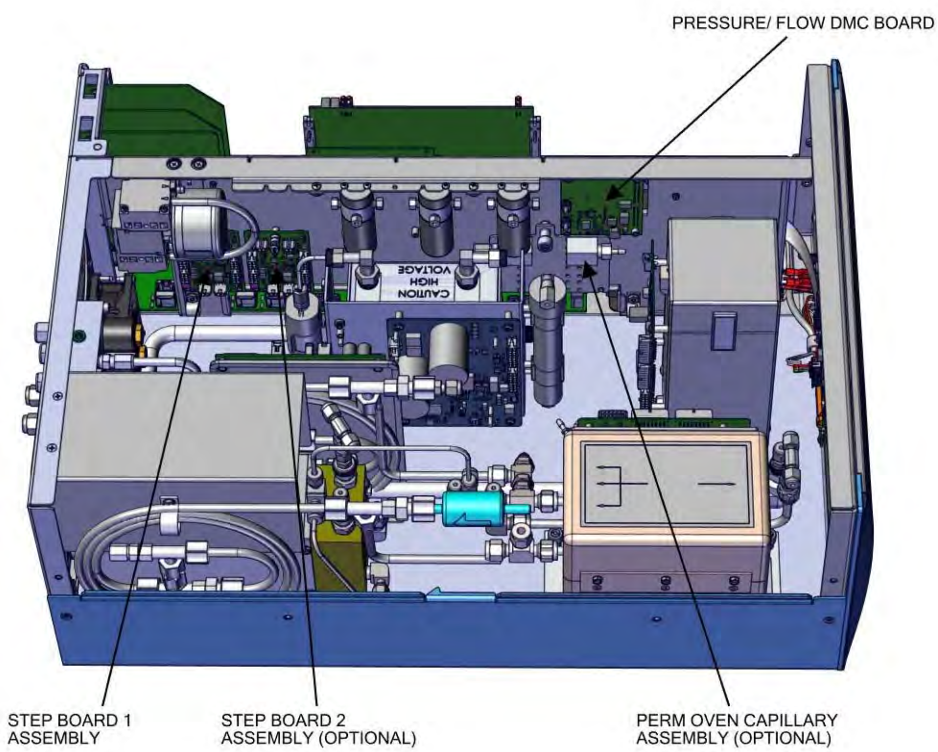


Figure 7–3. 42iQ Component Layout Side View

Fuse Replacement

Use the following procedure to replace the fuses.

1. Turn instrument OFF and unplug the power cord.
2. Remove fuse drawer, located on the AC power connector.
3. If either fuse is blown, replace both fuses.
4. Insert fuse drawer and reconnect power cord.

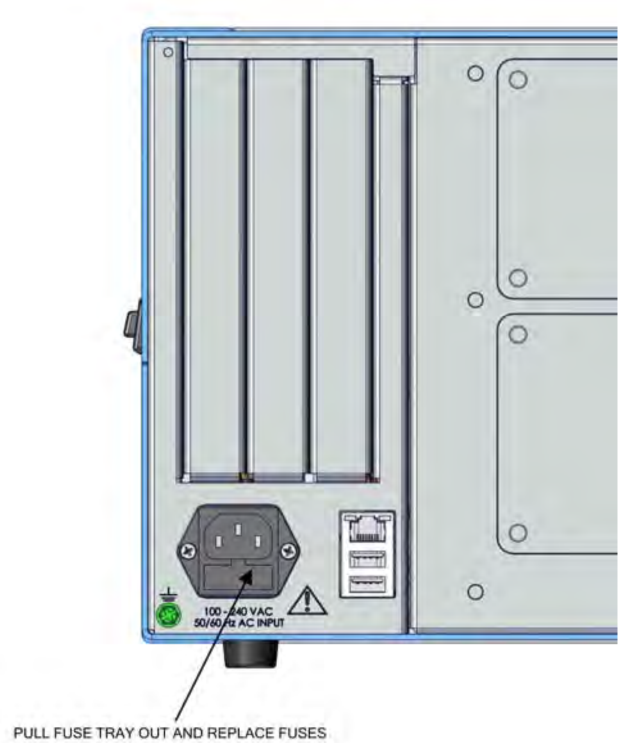


Figure 7–4. Replacing the Fuses

Filter Replacement

Use the following procedure to replace the filter.

1. Turn instrument OFF and unplug the power cord.
2. Starting with top right corner, pull out to remove fan cover.

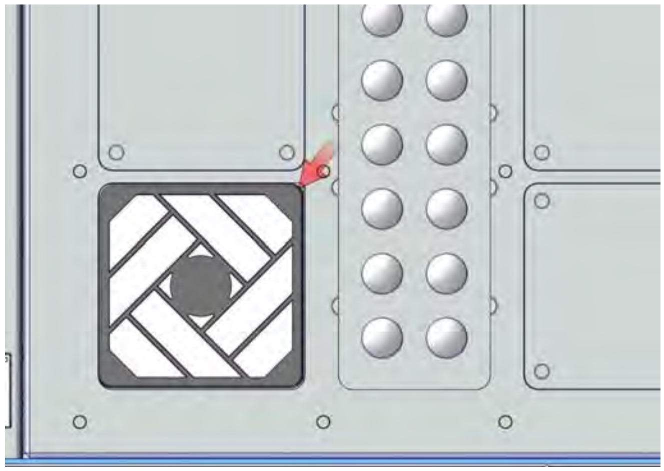


Figure 7–5. Start with Top Right Corner of Fan Cover

3. Replace filter and snap fan cover back in place.

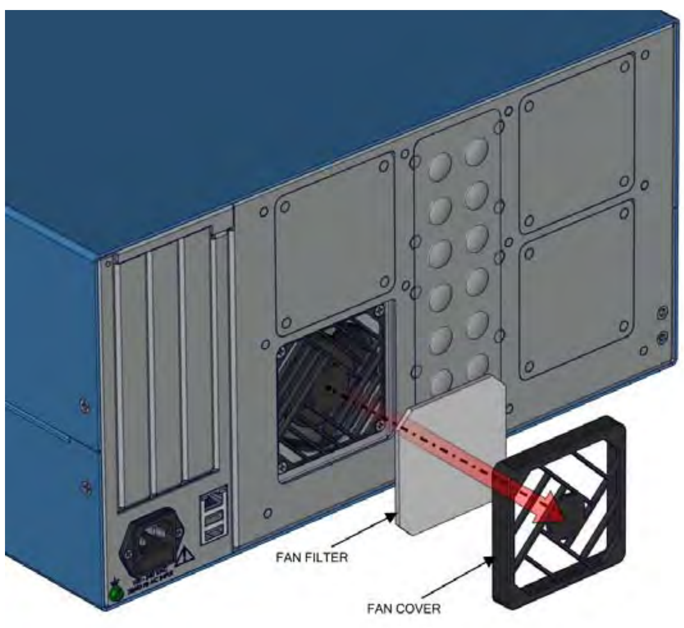


Figure 7–6. Removing the Fan Cover

Fan Replacement

Use the following procedure to replace the fan.

Equipment required:

Phillips drive, #2

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug the fan cable J18.

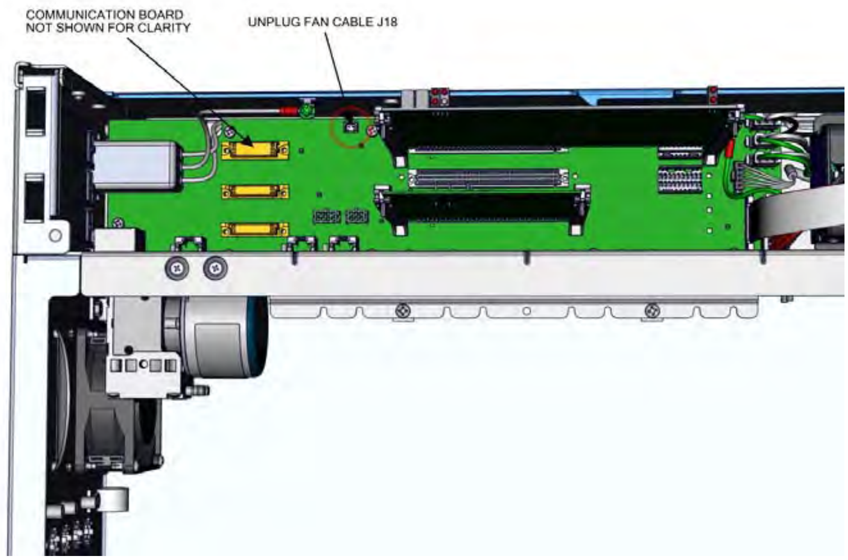


Figure 7–7. Unplugging the Fan Cable

3. Starting with top right corner, pull out to remove fan cover.

4. Unhook the four latches of the fan cover.

5. Unfasten the four 6-32 screws from the fan housing.

6. Replace fan and reassemble in reverse order.

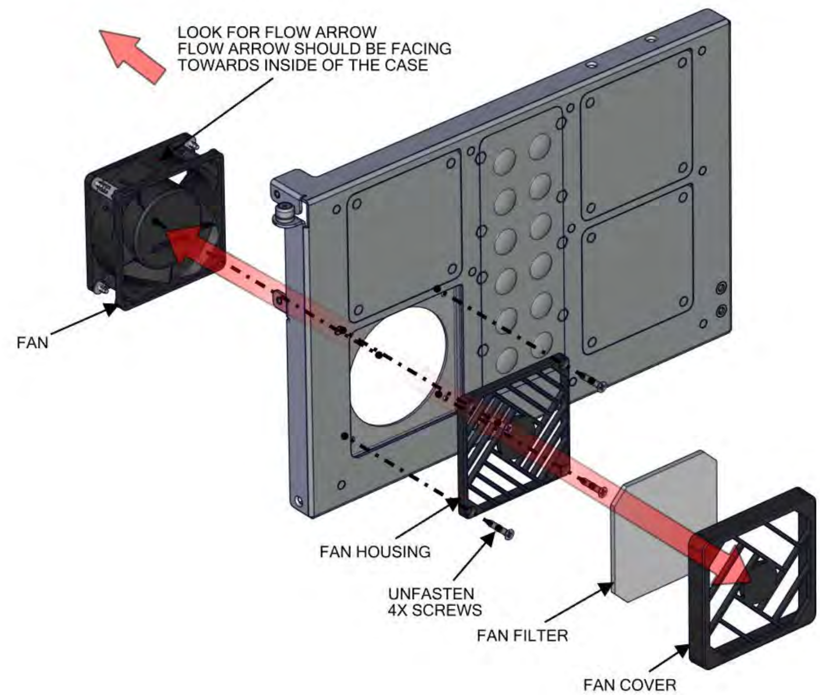


Figure 7–8. Replacing the Fan

Measurement Side Removal and Replacing

Use the following procedure to remove and replace the measurement side if necessary.

Equipment required:

Phillips drive, #2

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug the fan cable J18 (Figure 7–9).

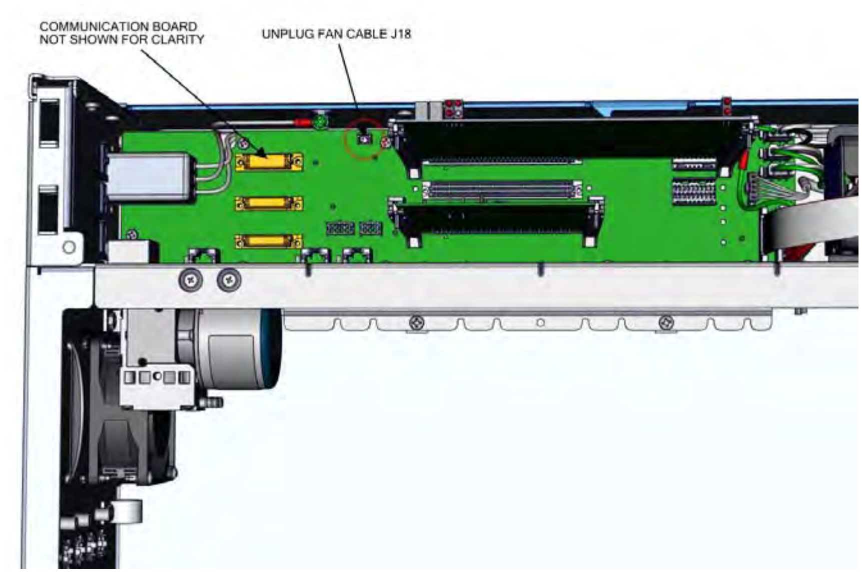


Figure 7–9. Unplugging the Fan Cable

3. Unplug DMC cable (Figure 7–10).

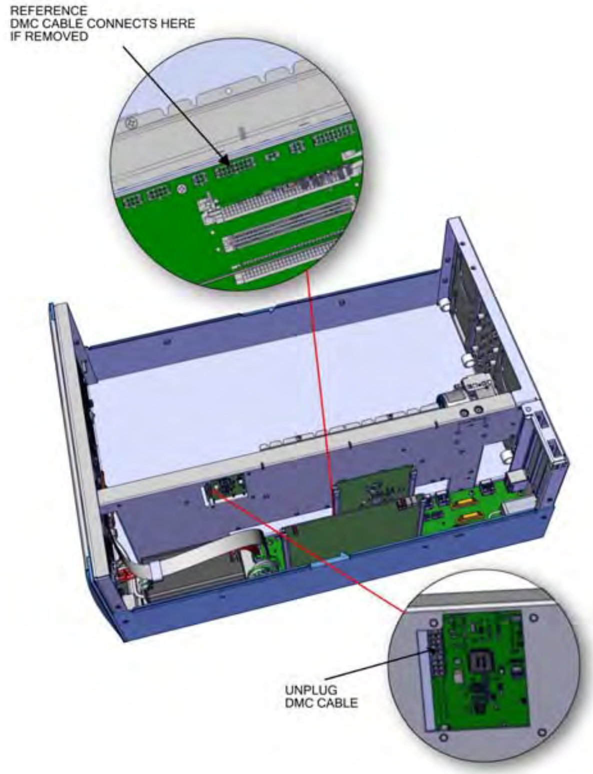


Figure 7–10. Unplugging the DMC Cable

4. Gripping from the top corners of the front panel and pull outwards.

5. Remove three 8-32 flat head screws (Figure 7–11).

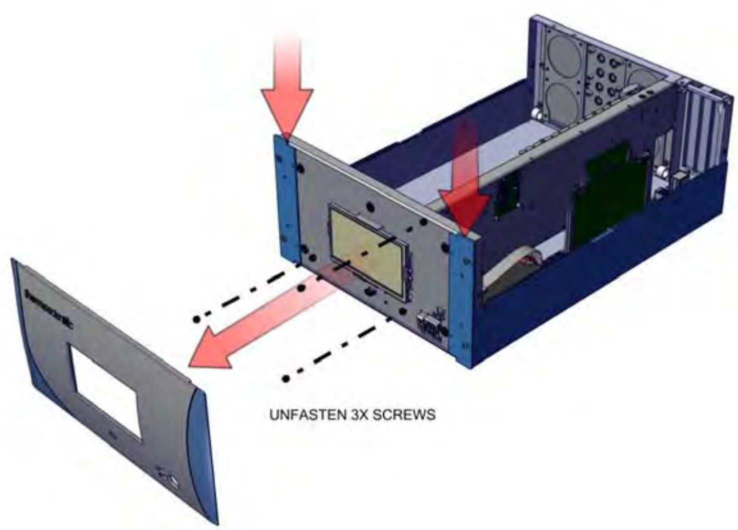


Figure 7–11. Unfasten Hardware Front for Measurement Side Removal

6. Swing arm open.

7. Unfasten captive hardware.

8. Remove two 8-32 flat head screws.

9. Pull measurement side out.

10. Replace and reassemble in reverse order.

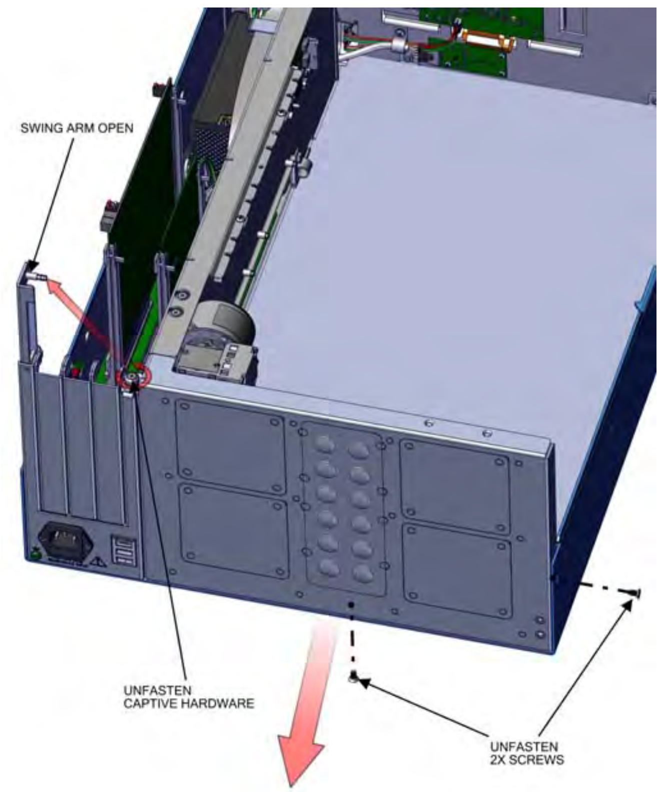


Figure 7–12. Unfasten Hardware Rear for Measurement Side Removal

LCD Module Replacement

Use the following procedure to replace the LCD module.

Equipment required:

Wrench, 1/4

1. Turn instrument OFF and unplug the power cord.

2. Gripping from the top corners of the front panel and pull outwards.

3. Unfasten four nuts (Figure 7–13).

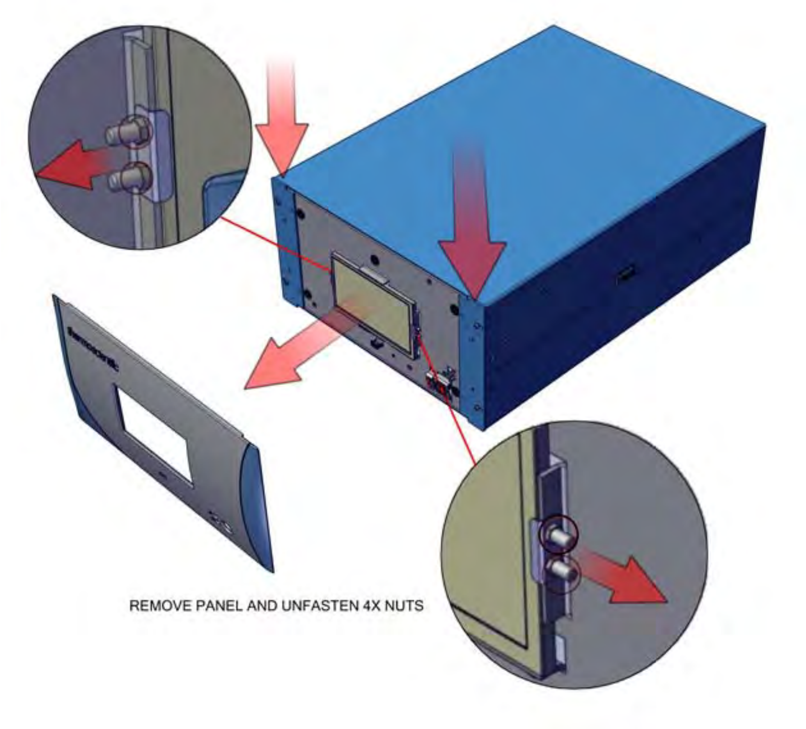


Figure 7–13. Replacing the LCD Module

4. Remove cover.

5. Unplug LCD cables from backside of board.

6. Pull board off the standoffs.

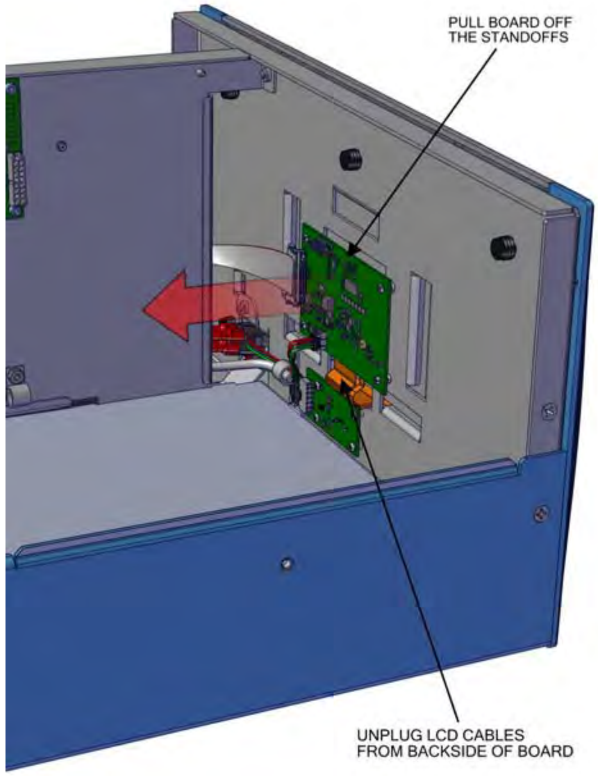


Figure 7–14. Remove Electrical Cables from LCD

7. Replace LCD module and reassemble in reverse order.

I/O Replacement

Use the following procedure to replace the I/O boards.

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Swing arm open.

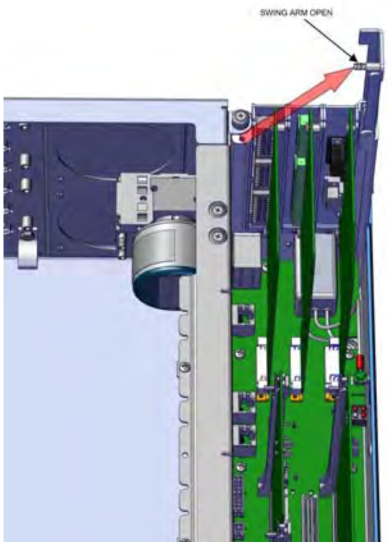


Figure 7–15. I/O Replacement, Arm

3. Pull board upwards.

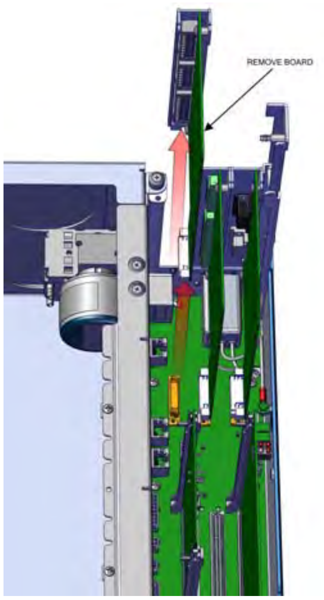


Figure 7–16. I/O Replacement, Remove Board

4. During install, make sure to align cutout circular to keyway.

5. Insert board downwards.

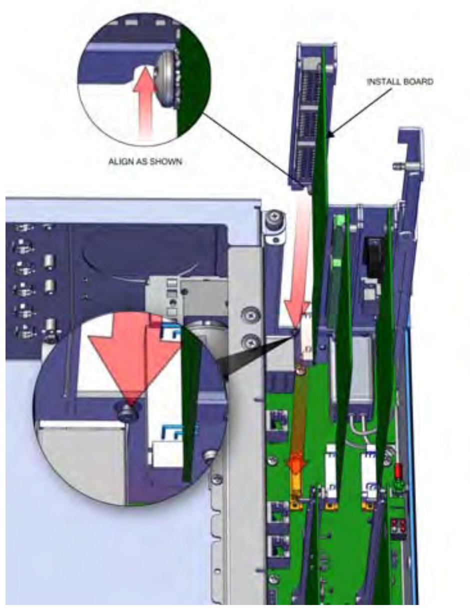


Figure 7–17. I/O Replacement, Install

6. Close arm. Make sure expansion bracket aligns to the inside of the rectangular cutouts.

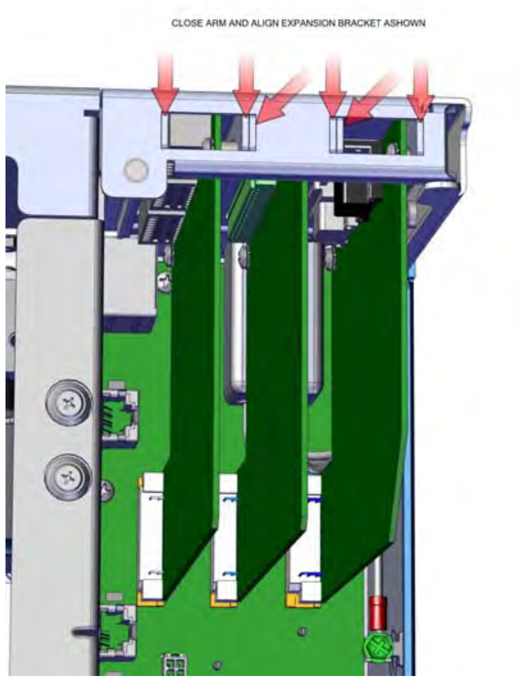


Figure 7–18. I/O Replacement, Close Arm Alignment

Peripherals Support Board and System Controller Board Replacement

Use the following procedure to replace the peripherals support board or system controller board.

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Pull tab out (two per board).

3. Pull board out.

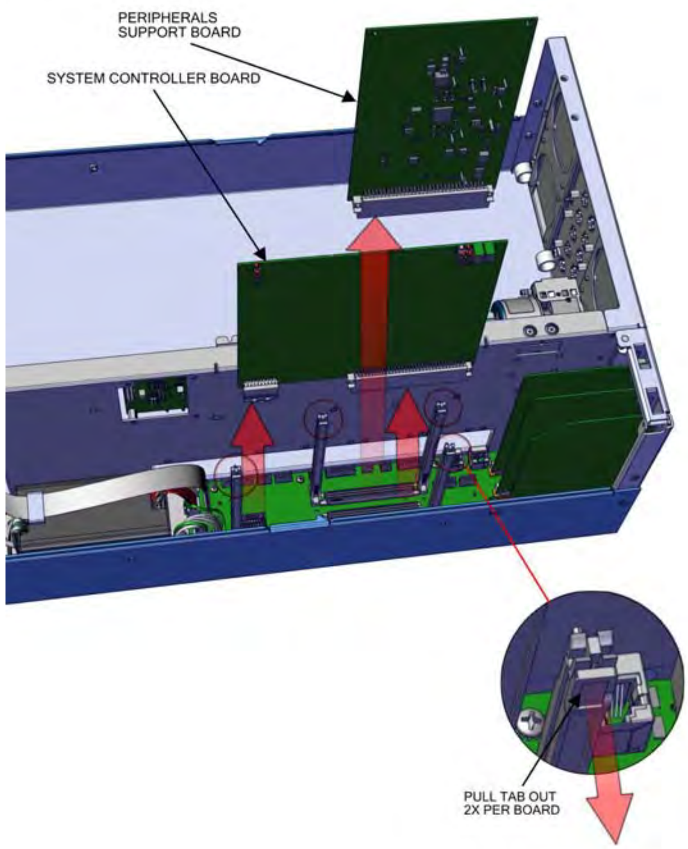


Figure 7–19. Replacing the Peripherals Support or System Controller Board

4. Replace board and reassemble in reverse order.

DMC Pressure and Flow Board

Use the following to replace the DMC pressure and flow board.

Equipment required:

Hex drive, 7/16

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug cables from the pressure and flow board.

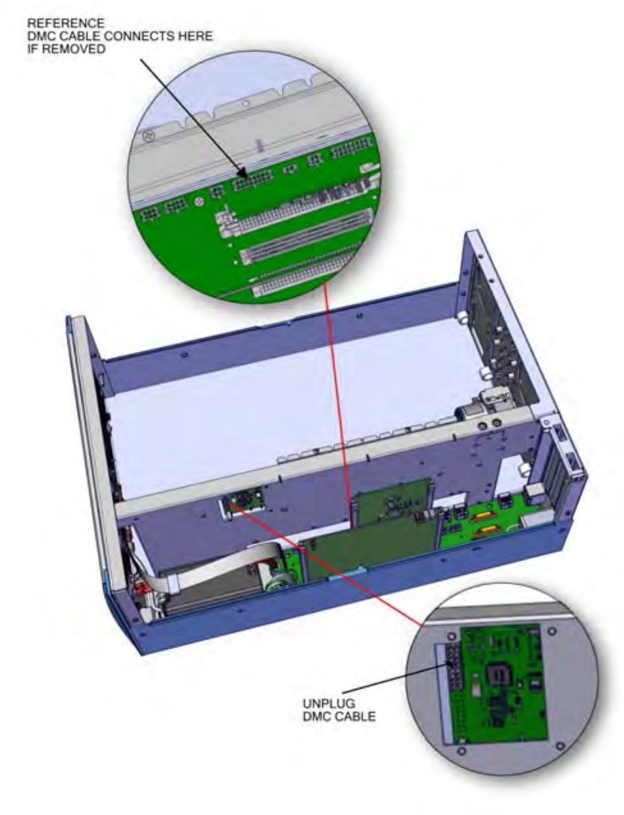


Figure 7–20. Flow Pressure Board, Disconnect DMC Cable

3. Disconnect plumbing.

4. Using 7/16 hex drive, unfasten four #6-32 socket cap head screws.

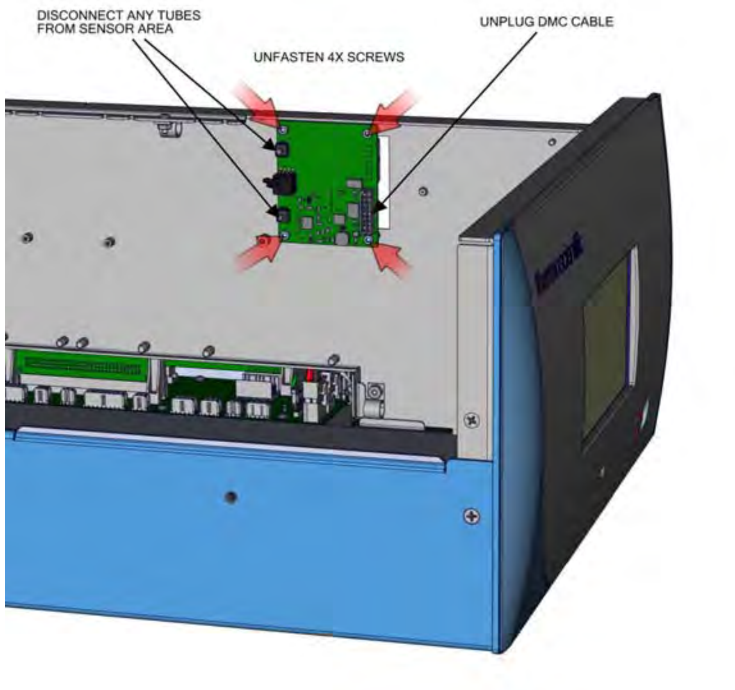


Figure 7–21. Flow Pressure Board, Screws

5. Replace board and reassemble in reverse order.

Pump Replacement

Use the following procedure to replace the pump.

Equipment required:

Phillips drive, #1 and #2

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug pump cable from step pol board J7.

3. Twist opposite direction to unlock tube clamps.

Note Push in tube clamp to lock. ▲

4. Disconnect tubing from pump.

5. Unfasten two captive hardware.

6. Slide pump left until keyway meets opening.

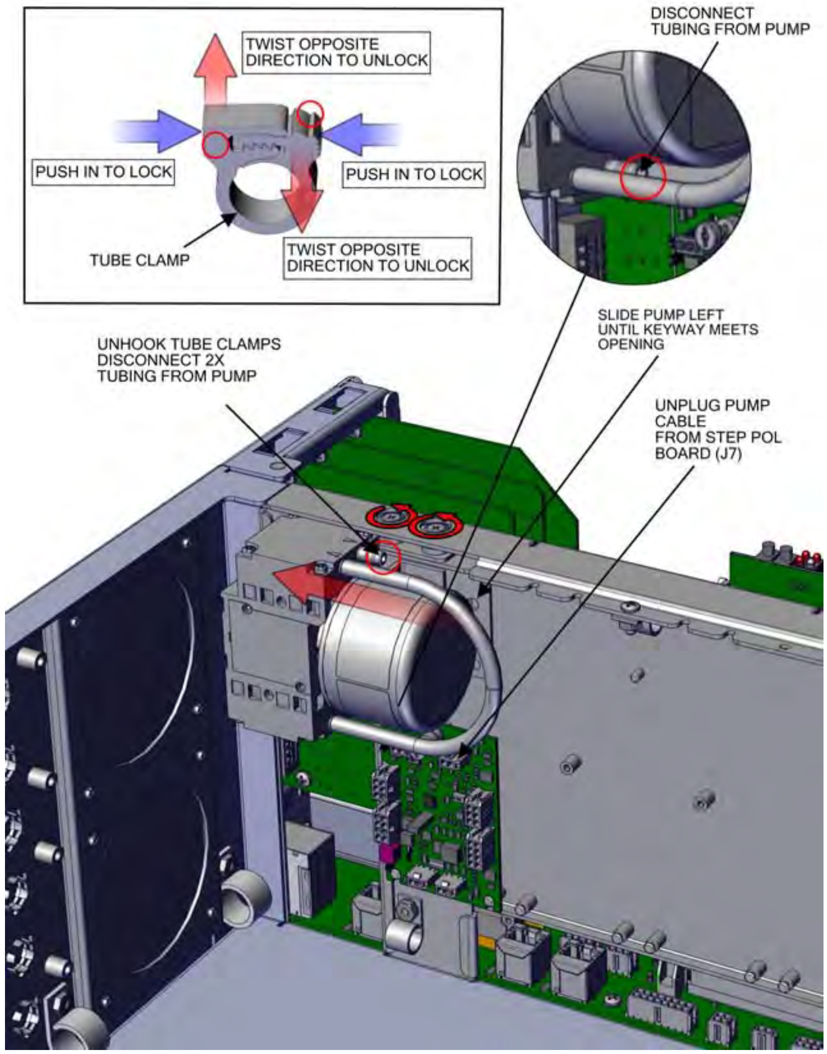


Figure 7–22. Remove Pump, Disconnect and Unfasten

7. Pull pump outwards.

Note When installing pump, make sure the pump keyway opening goes over the keyway. ▲

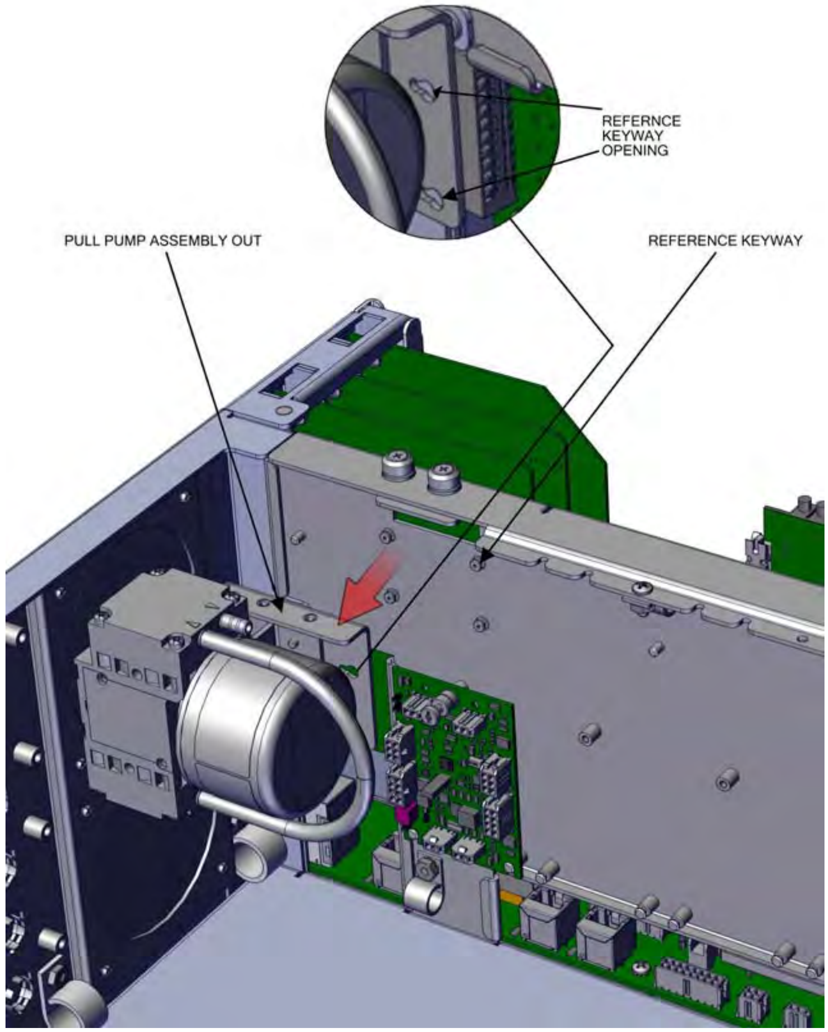


Figure 7–23. Pump Removal, Keyway

8. Remove two screws.

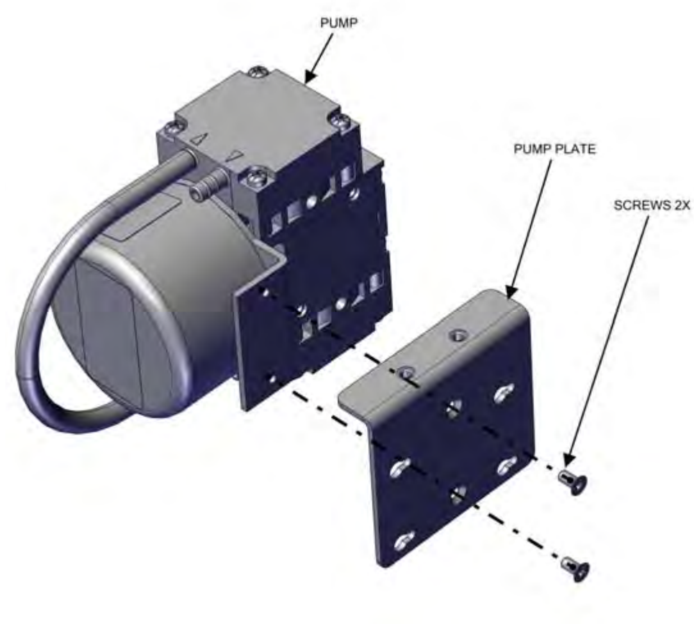


Figure 7–24. Pump replacing, Unfasten Screws

9. Replace pump and reassemble in reverse order.

Capillary Cleaning and/or Replacement

Use the following procedure to clean or replace the capillary.

Equipment required:

Phillips drive, #2

Hex drive, 7/64

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Disconnect the plumbing.

3. Using #2 Phillips drive, unfasten captive hardware.

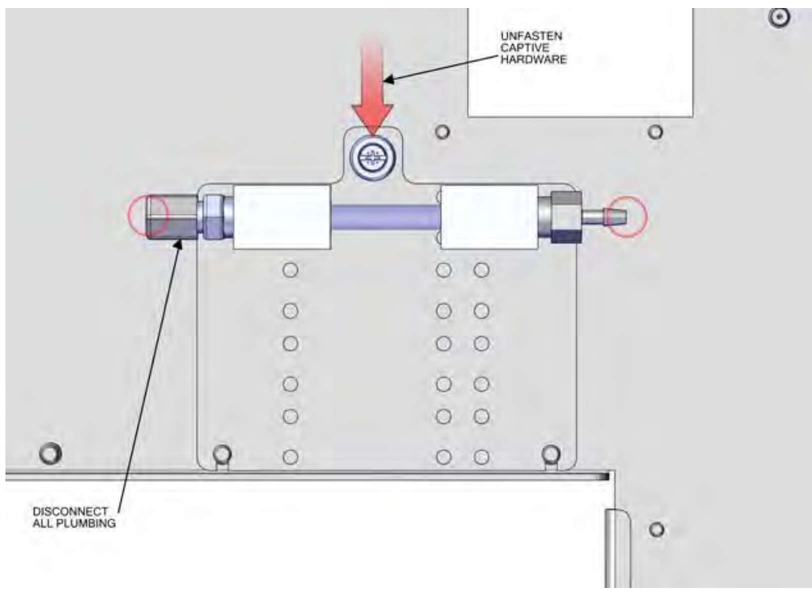


Figure 7–25. Remove Capillary, Disconnect and Unfasten

4. Slide capillary plate upwards clearing the partition panel keyway.

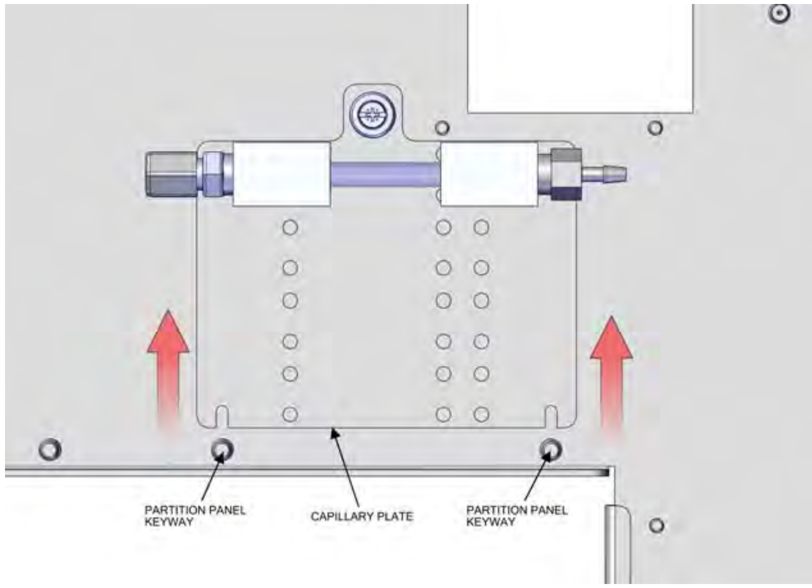


Figure 7–26. Capillary Plate, Keyway

5. Using 7/64 hex drive, remove four #6-32 socket cap head screws.

6. Pull apart the capillary blocks.

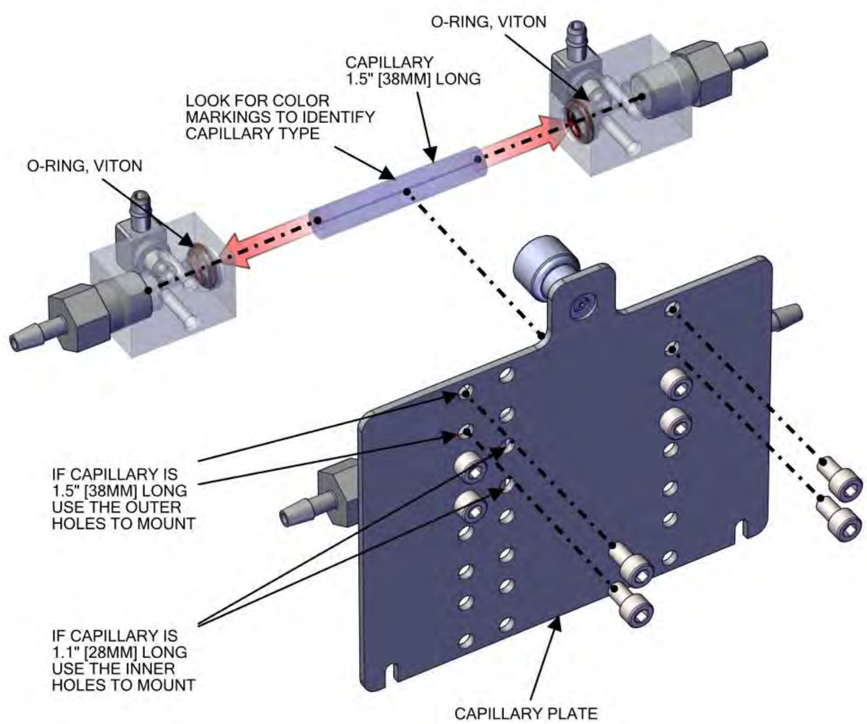


Figure 7–27. Capillary and O-Ring Replace

7. Replace capillary and reassemble in reverse order.

Note Fitting arrangements, number of capillaries and capillary sizes will vary per instrument configuration. ▲

Capillary O-Ring Replacement

Use the following procedure to replace the capillary o-rings.

Equipment required:

O-ring pick tool

1. Using a plastic o-ring pick tool, remove the o-ring.

Note Be careful in not damaging the o-ring walls during this process. Refer to Figure 7–27. ▲

Power Supply Replacement

Use the following procedure to replace the power supply.

Equipment required:

Phillips drive, #2

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug all electrical shown J9, J10, J24, J25, J26, and ground.

3. Unfasten captive hardware.

4. Slide power supply left, clearing three case floor plate keyways.

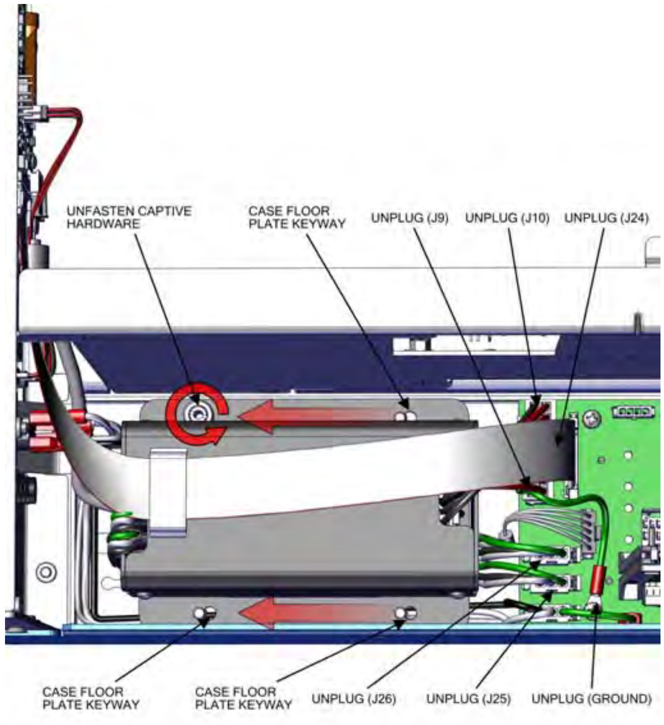


Figure 7–28. Removing Power Supply

5. Pull power supply up.

6. Replace power supply and reassemble in reverse order.

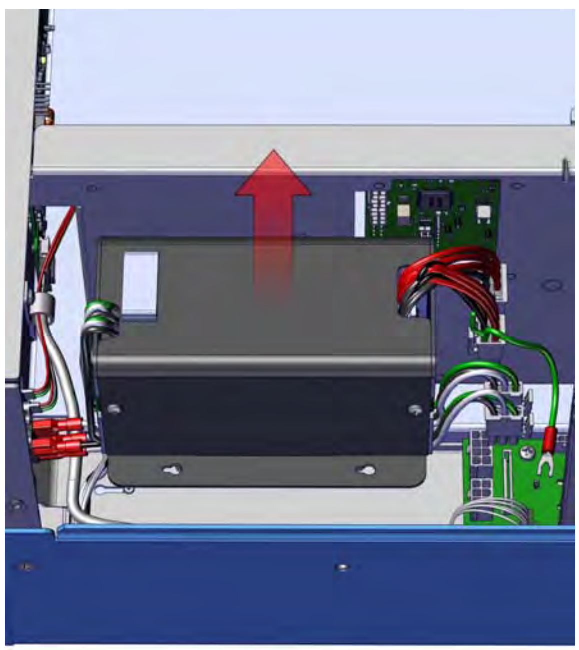


Figure 7–29. Replacing Power Supply

Step POL Board Replacement

Use the following procedure to replace the Step POL Board.

Equipment required:

Torque screwdriver, T15 or Slot screwdriver, 3/16

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug step pol power cable J4.

3. Unplug step pol signal cable J2.

4. Unplug pump cable J7.

5. Unfasten captive hardware.

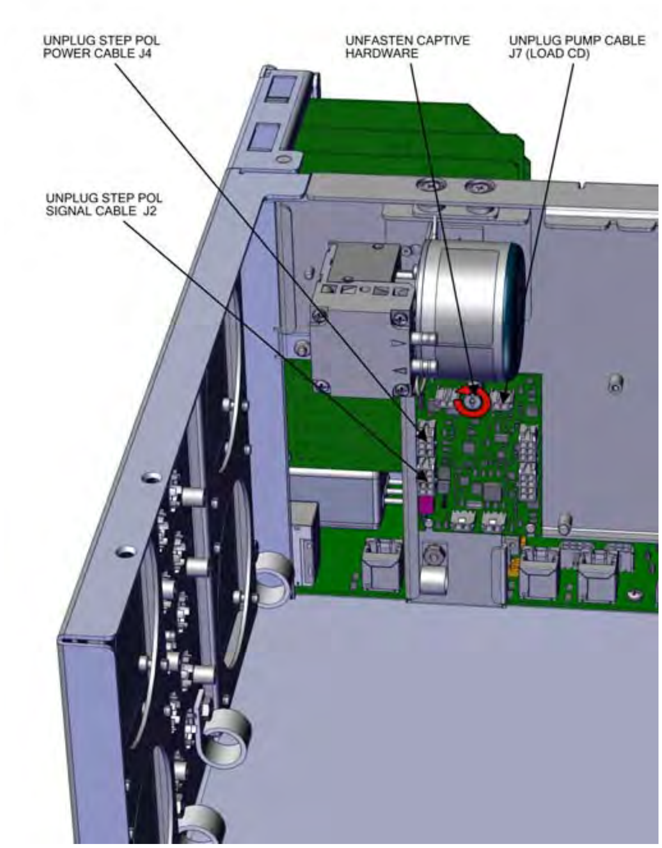


Figure 7–30. Unplug and Unfasten Step POL Board

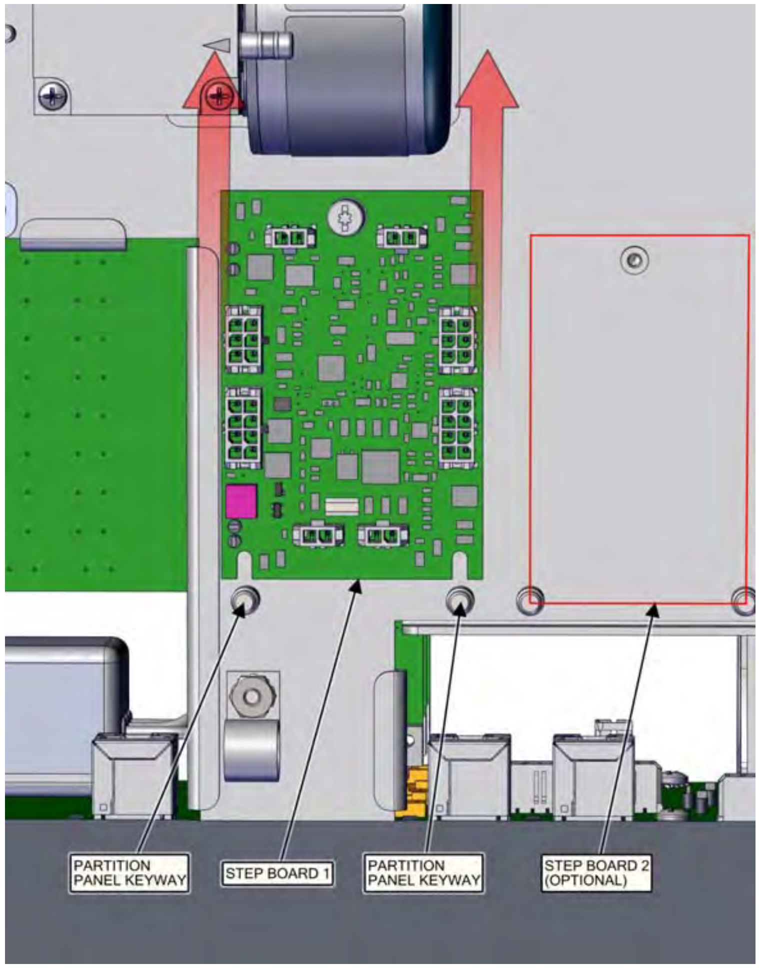


Figure 7–31. Clear Partition Keyway Step POL Board

6. Slide step board 1 upwards clearing the partition panel keyway.

7. If replacing step board 1, make sure switch 1 and 2 are pointed away from ON (Figure 7–32). If replacing optional step board 2, make sure switch 1 is pointed towards ON and switch 2 is pointed away from ON (Figure 7–32).

8. Replace step pol board and reassemble in reverse order.

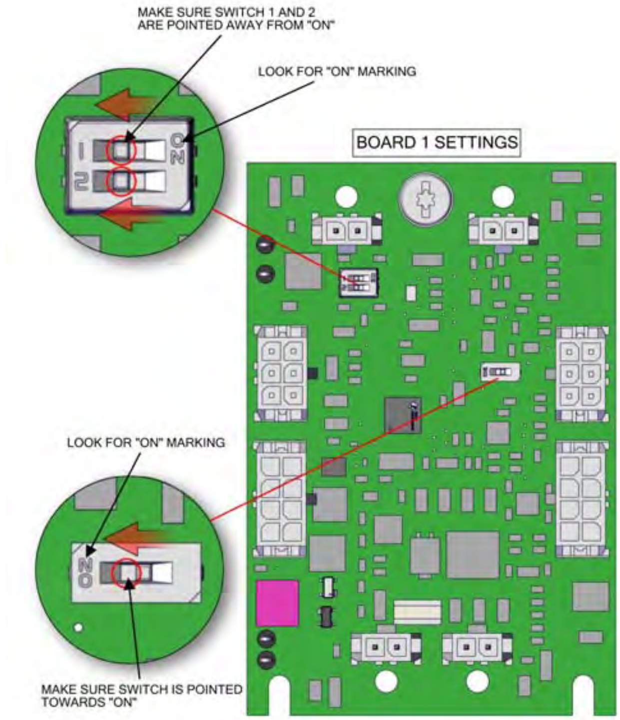


Figure 7–32. Step POL Board 1 Switch Settings

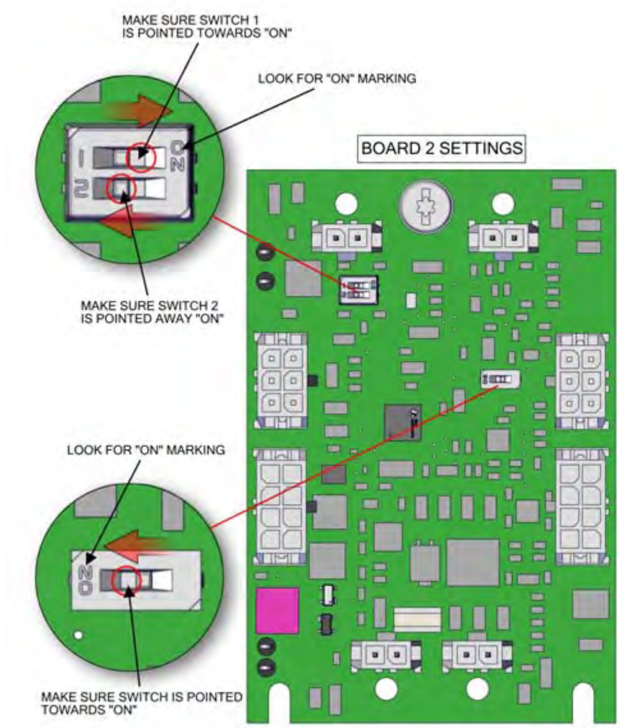


Figure 7–33. Replace Step POL board pt 2

DMC PMT Cooler and Reaction Chamber Replacement

Use the following procedure to replace the PMT cooler and clean or replace the reaction chamber assembly.

- Remove the PMT Cooler
- Replacing the PMT board
- Removing and Cleaning the Reaction chamber
- Replacing the PMT Cooler and Reaction chamber
- PMT Replacement

PMT Cooler Shroud Removal

Use the following procedure to remove the PMT cooler from the instrument.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

WARNING Make sure the PMT has cooled down before touching. ▲

2. Unhook plumbing by pulling loop downwards and unhook tubing.
3. Using a #2 Phillips drive, unfasten two 6-32 flat head screws.
4. Pull shroud outwards.

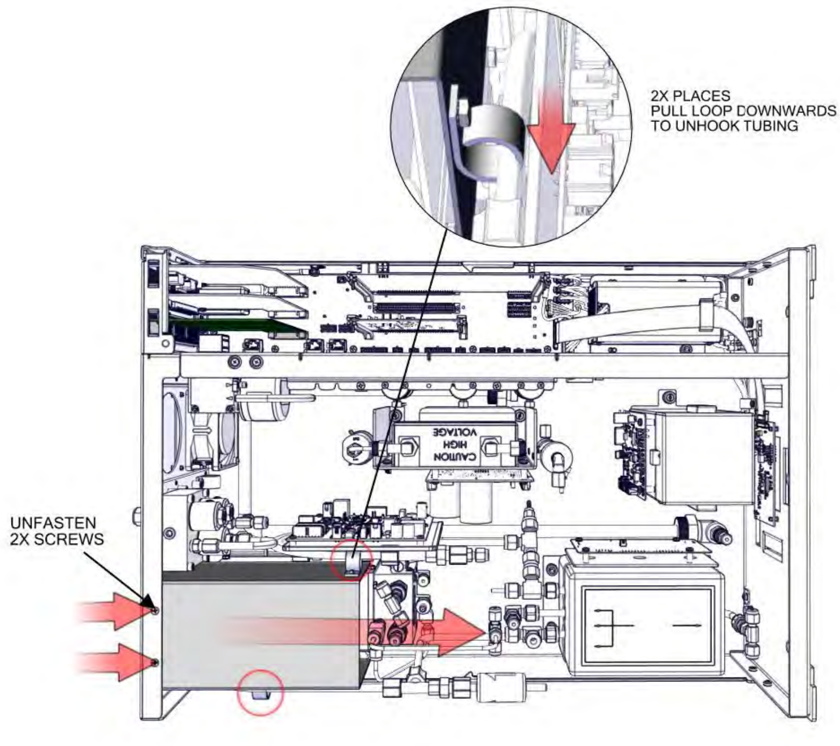


Figure 7–34. Remove PMT Cooler Shroud

5. Unplug J3, J1, and J6 (fan).

6. Disconnect all plumbing depending on the options. Configuration plumbing connections will vary.

7. Using #2 Phillips drive, unfasten four captive hardware.

8. Pull PMT cooler upwards.

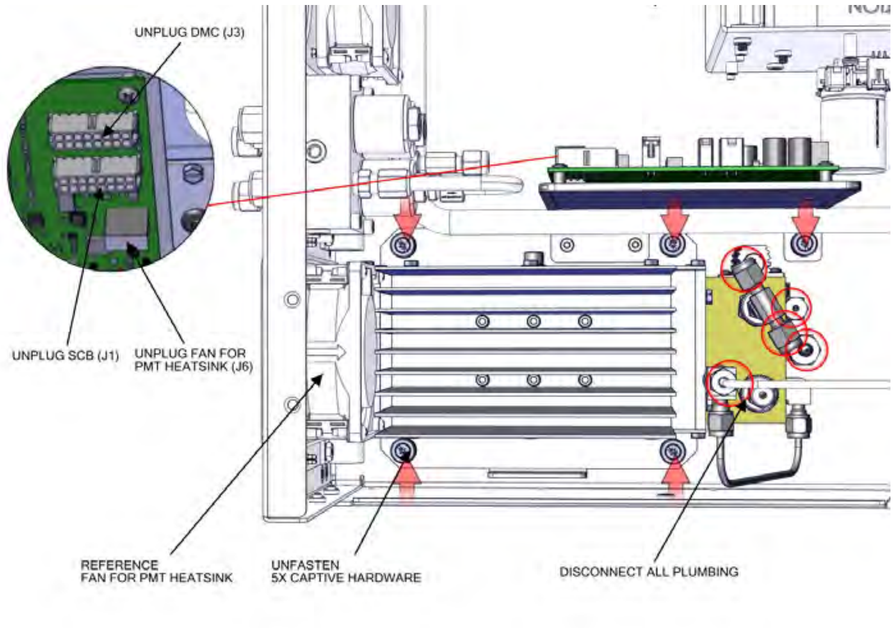


Figure 7–35. Remove PMT Cooler

PMT Cooler Board Replacement

Use the following procedure to replace the PMT cooler board.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover.
2. Remove DMC Converter as described in "PMT Cooler Shroud Removal" in this chapter.
3. Unplug all electrical connections from the board.
4. Using a #2 Phillips drive, unfasten six #6-32 pan head screws.
5. Pull board outwards.

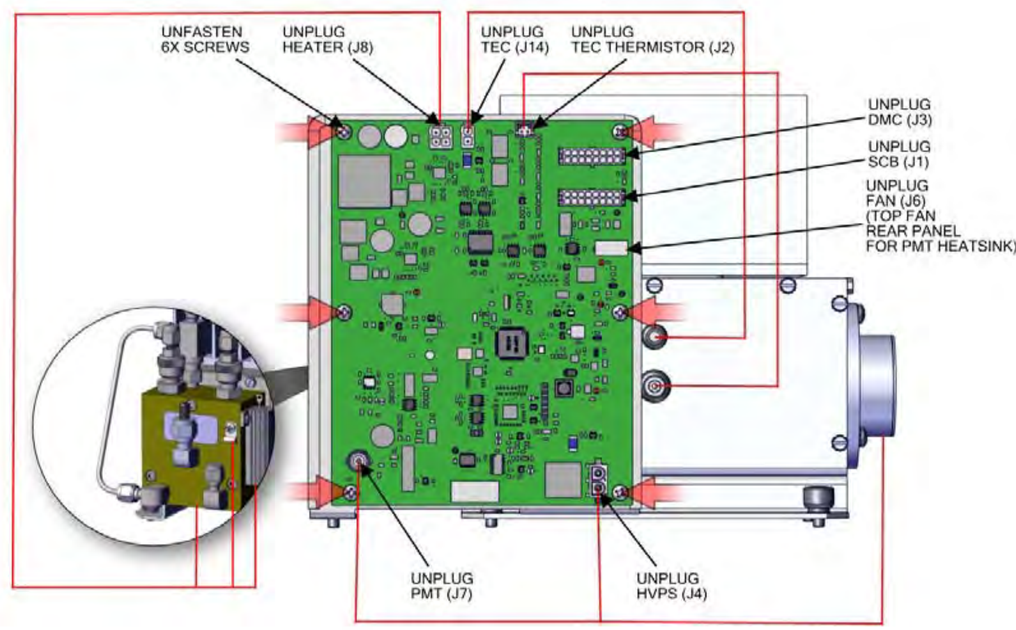


Figure 7–36. Remove PMT Cooler Board

Reaction Chamber Cleaning and/or Removal

Use the following procedure to clean or remove the reaction chamber.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover.

2. Remove DMC Converter as described in "PMT Cooler Shroud Removal" in this chapter.

3. Unplug heater J8 from board.

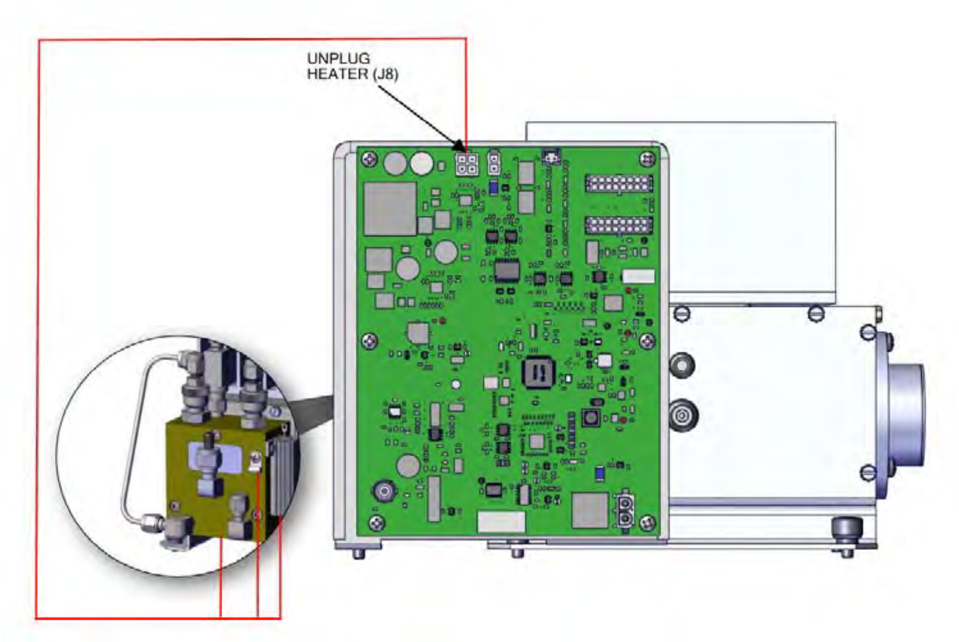


Figure 7–37. Photo Reaction Chamber Cleaning, Electrical

4. Disconnect plumbing as shown.

5. Using a 9/64-inch hex drive, unfasten three #8-32 socket cap head screws.

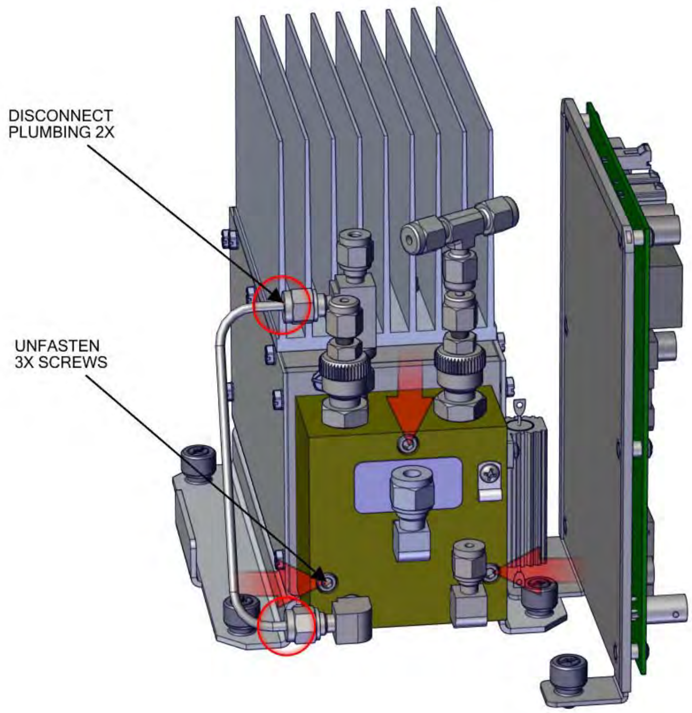


Figure 7–38. Photo Reaction Chamber Cleaning, Hardware

6. Pull reaction chamber outwards.

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling an internal component. ▲

7. To reinstall reaction chamber, follow previous steps in reverse, making sure to back fill the cooler with dry air or nitrogen prior to installing reaction chamber.

8. Reinstall the measurement bench. Refer to Figure 7–37 and Figure 7–44.

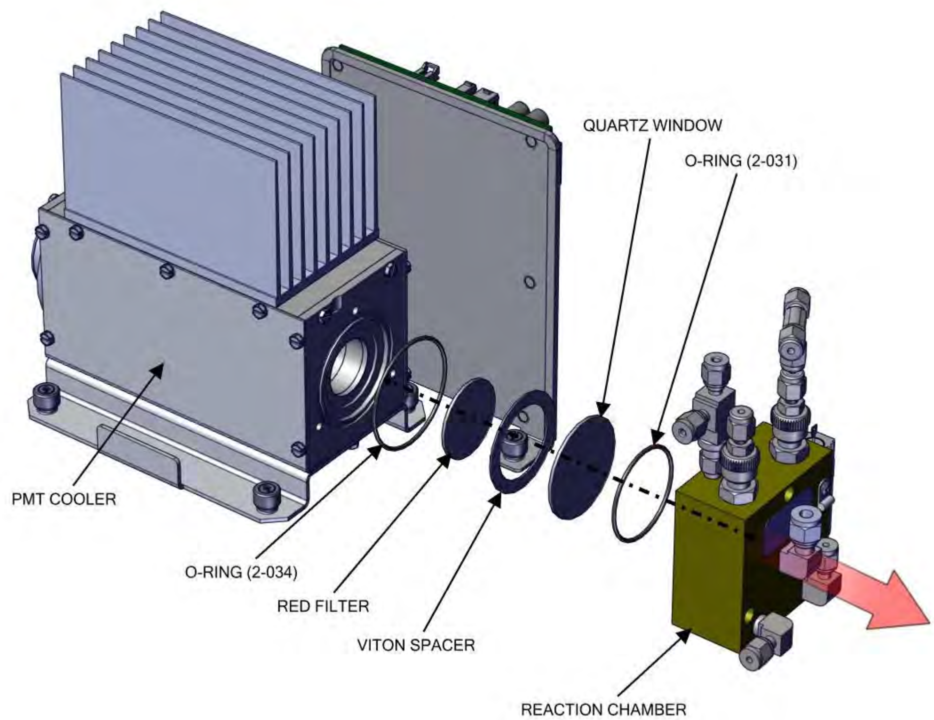


Figure 7–39. Photo Reaction Chamber Cleaning, Window

Photomultiplier Tube (PMT) Replacement

Use the following to replace the photomultiplier tube (PMT).

Equipment Required:

Screwdriver, flat head

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

2. Unplug electrical connections PMT (J7) and HVPS (J4).

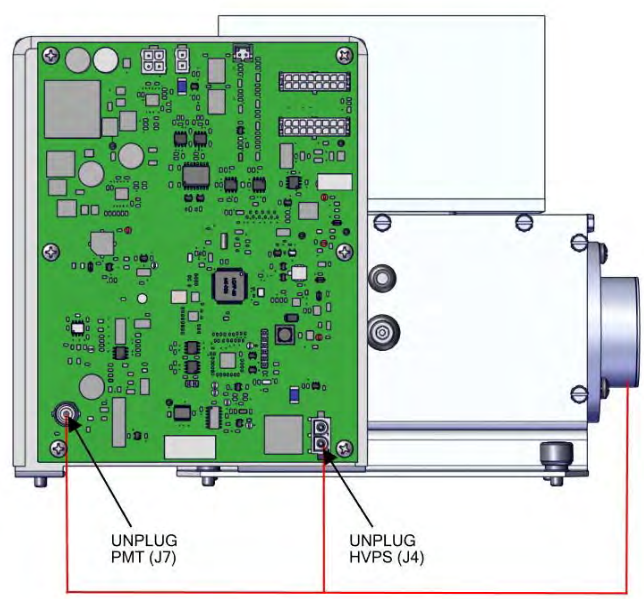


Figure 7–40. PMT Tube Replace-Elec-Pt1

3. Using a flat head screwdriver, wedge out of top right corner starting point, labeled 1 (Figure 7–57).

4. Continue to wedge out the four midpoints of the plate to remove the snap on access panel, labeled 2 (Figure 7–58).

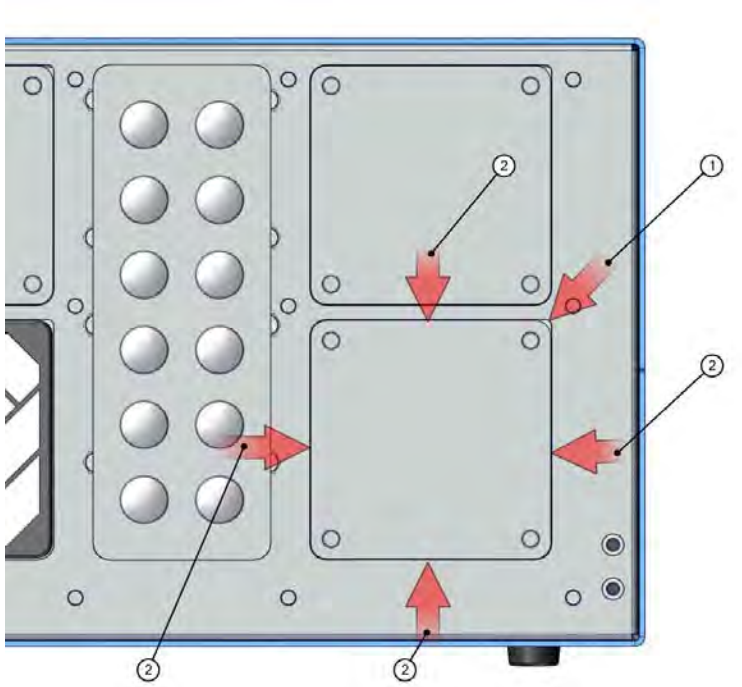


Figure 7–41. Removing the Access Panel, Starting Point

5. .Pull access cover out.

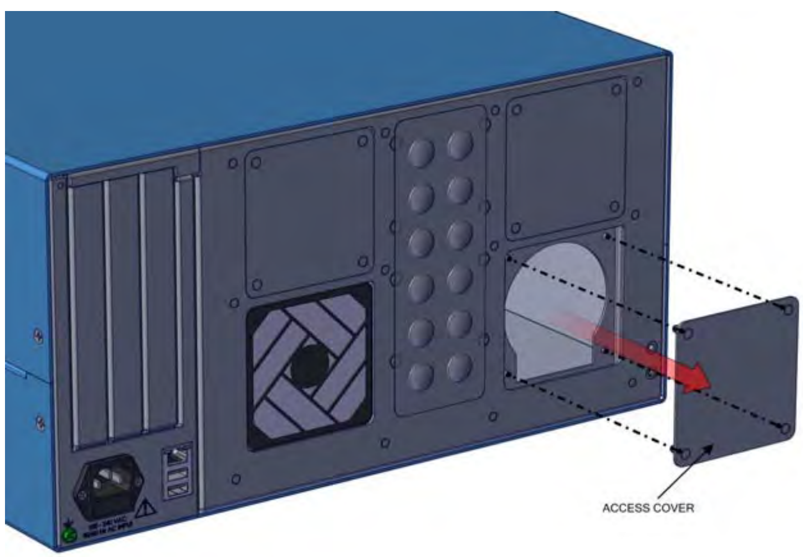


Figure 7–42. Access Cover

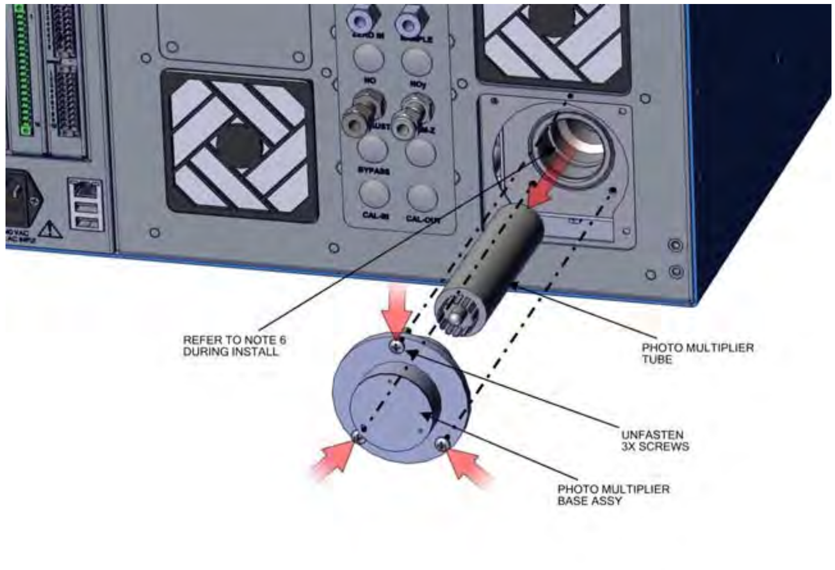


Figure 7–43. PMT Tube Replace-Screws

6. Using a #2 Phillips drive, unfasten three 8-32 pan head screws.

Equipment Damage Do not point the photomultiplier tube at a light source. This can permanently damage the tube. ▲

7. Pull the PMT and PMT base from cooler assembly by twisting it slightly back and forth.

8. To install PMT, follow previous steps in reverse order making sure to backfill the cooler with dry air or nitrogen prior to replacing the PMT.

9. Perform a PMT calibration as described on page 3-87.

DMC Converter Replacement

Use the following procedure to replace the converter.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover.

2. Unplug DMC cables 2X.

3. Disconnect all plumbing 8X.

Note The amount of connections will vary depending on the different options installed. ▲

4. Using a #2 Phillips drive, unfasten captive hardware 4X.

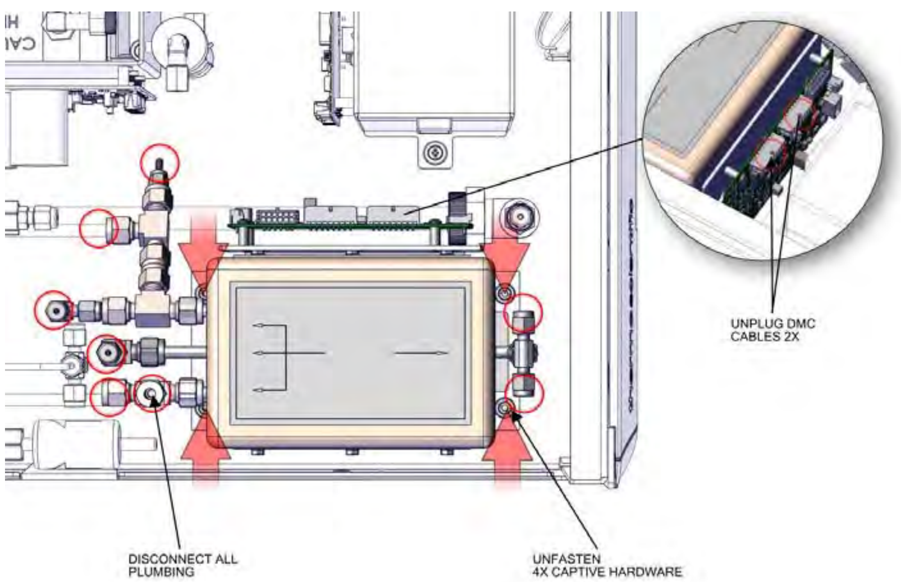


Figure 7–44. Converter DMC Assembly Remove

Converter Assembly Board Replacement

Use the following procedure to replace the converter assembly board.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover.

2. Remove DMC Converter as described in "DMC Converter Replacement" in this chapter.

3. Unplug electrical J6 and J7.

4. Using a #2 Phillips drive, unfasten four 6-32 pan head screws.

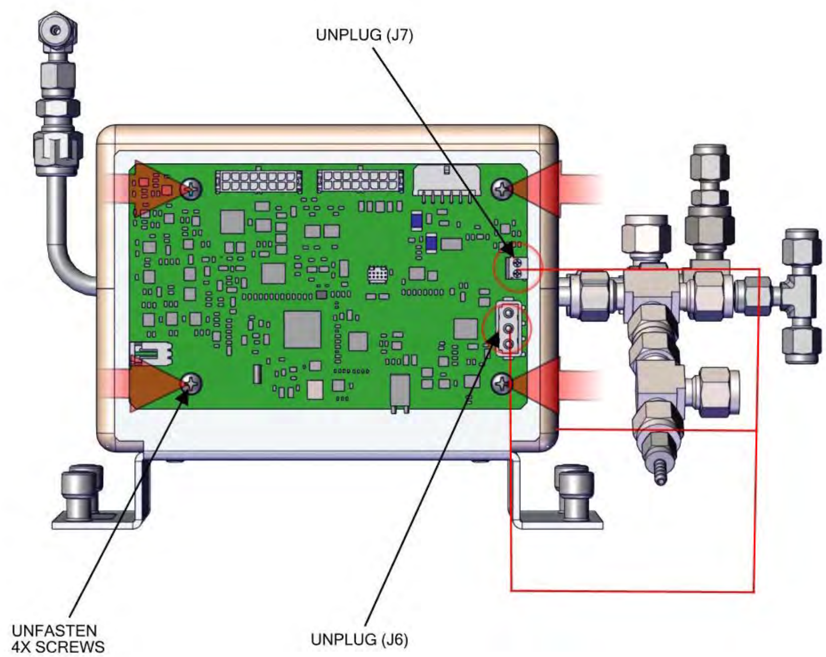


Figure 7–45. Converter Assembly Remove bd

5. Pull converter assembly board outwards.

6. Replace converter assembly board and assemble in reverse order.

Converter Cartridge Heater Replacement

Use the following procedure to replace the converter cartridge heater.

Equipment Required:

Phillips drive, #2

Hex drive, 1/4-inch

1. Turn the instrument OFF, unplug the power cord, and remove the cover.

2. Remove DMC Converter as described in "DMC Converter Replacement" in this chapter.

3. Using a 1/4-inch hex drive, unfasten six 6-32 hex head screws.

4. Take apart top housing assembly and insulator to get to the heater assembly.

5. Remove the converter cartridge/heater assembly from the bottom housing assembly.

6. Remove fitting body to allow clearance for heater to slide out.

7. Loosen the heater clamp, pry heater apart no wider than necessary and remove the converter cartridge noting the proper orientation of heater wires and thermocouple probe.

8. To replace converter, follow previous steps in reverse. Note be sure to wrap the O_3 converter tube snugly around the heater.

9. Reinstall in reverse order.

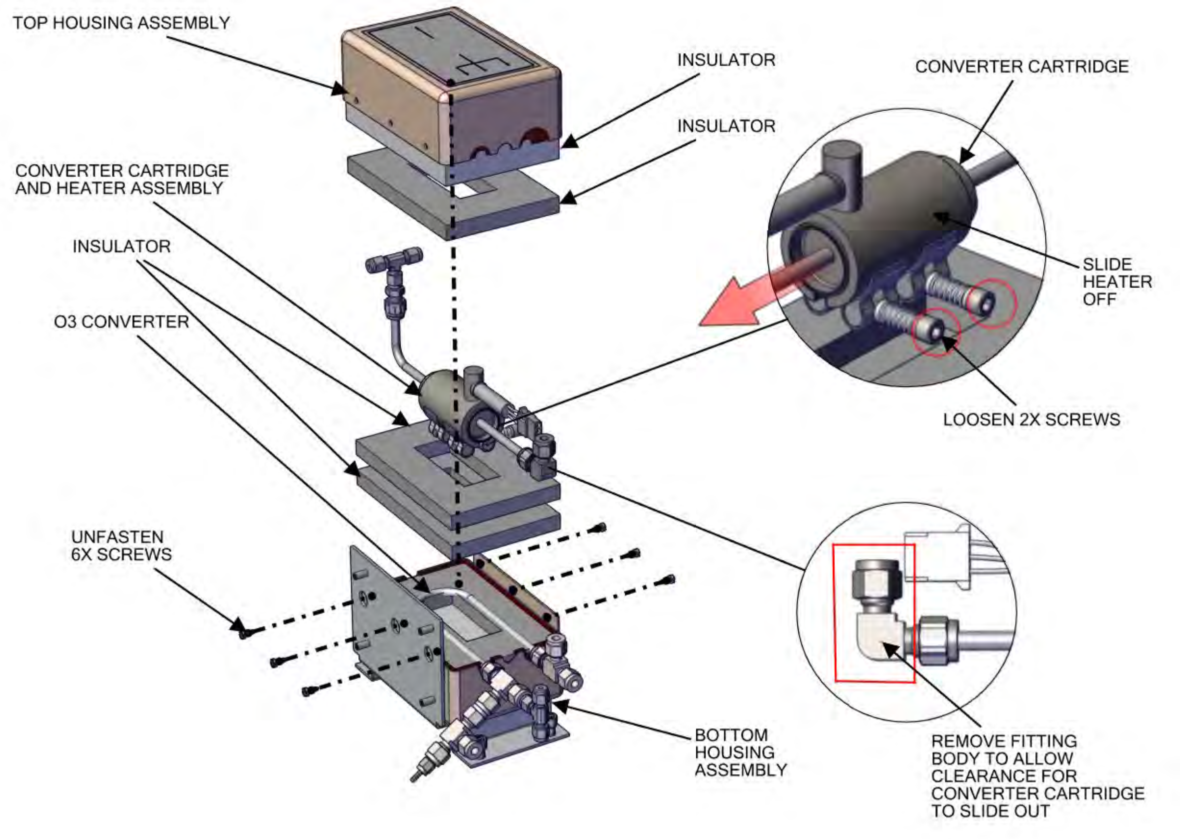


Figure 7–46. Converter Assembly Replace Heater

DMC Ozonator

Use the following procedure to replace the ozonator and transformer board, replace the flow switch and optional ammonia scrubber.

- Removing the ozonator and transformer
- Replacing the ozonator and transformer board
- Replacing the flow switch
- Replacing the ammonia scrubber (optional)

Ozonator and Transformer Removal

Use the following procedure to remove the ozonator and transformer.

Equipment Required:

Phillips drive, #2

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

2. Unplug DMC converter DMC (J2) and flow pressure board (J4).

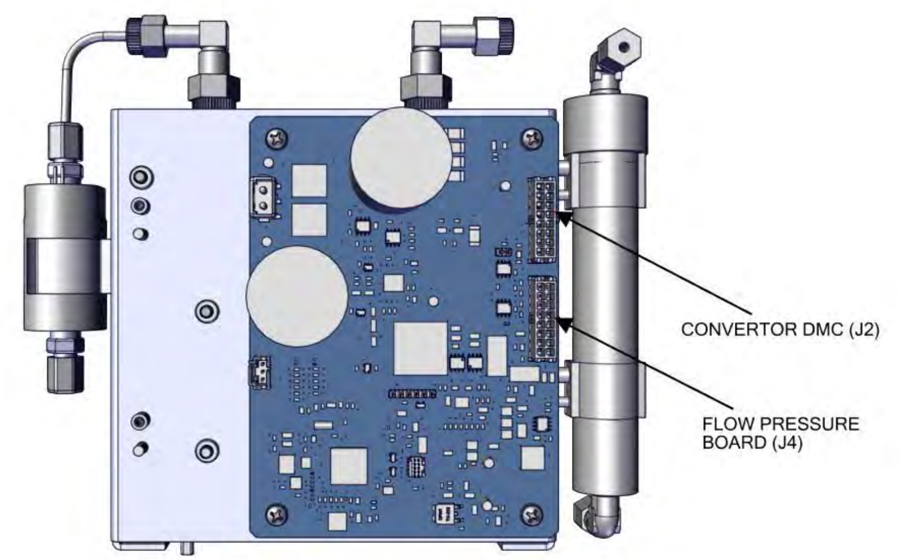


Figure 7–47. HVPS, Electrical

3. Disconnect plumbing.

4. Using a #2 Phillips drive, unfasten captive hardware 4X.

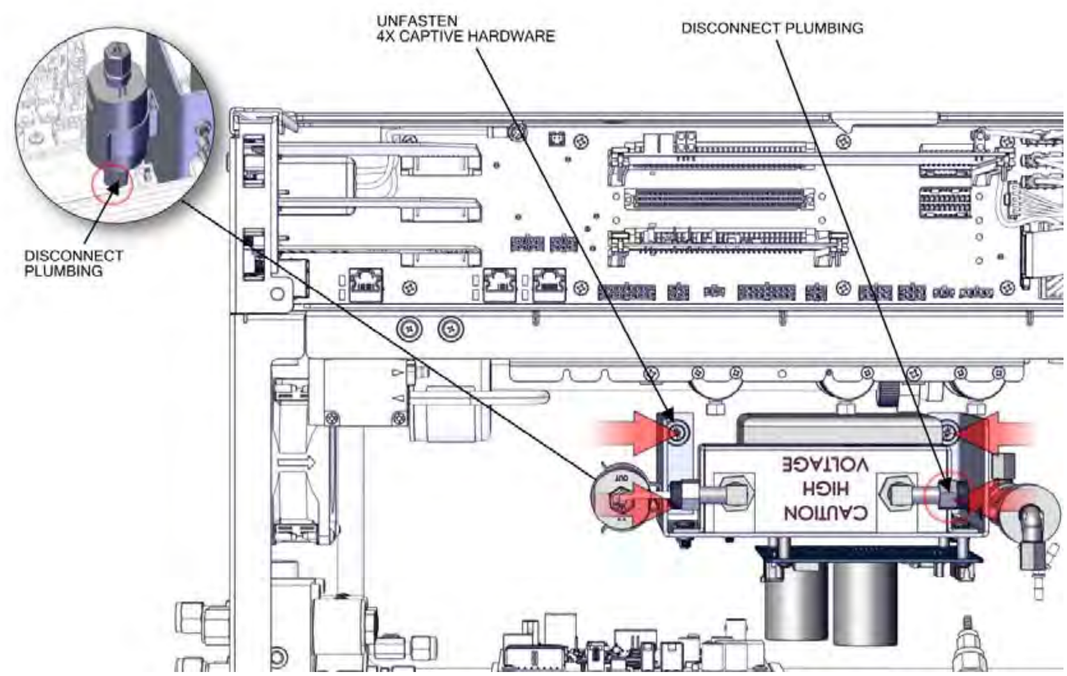


Figure 7–48. HVPS Remove

Ozonator Replacment

Use the following procedure to replace the ozonator.

1. Unplug ozonator (J1).

2. Disconnect plumbing 2X.

3. Ozonator—using a #2 Phillips drive, unfasten two #6-32 pan head screws.

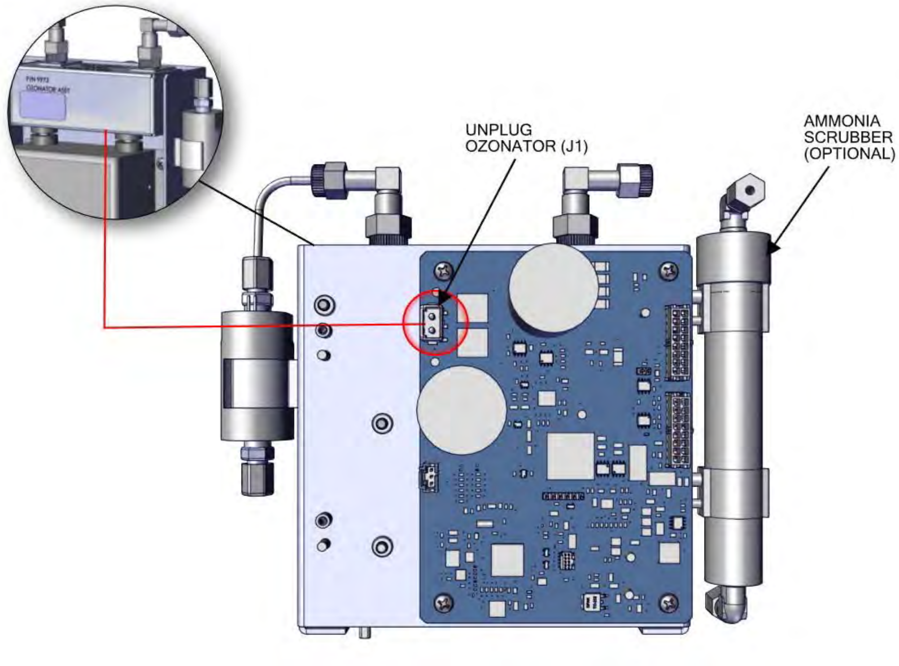


Figure 7–49. Replace Ozonator

Transformer Replacement

Use the following procedure to replace the transformer.

1. Ozonator transformer—using a #2 Phillips drive, unfasten four #6-32 pan head screws.

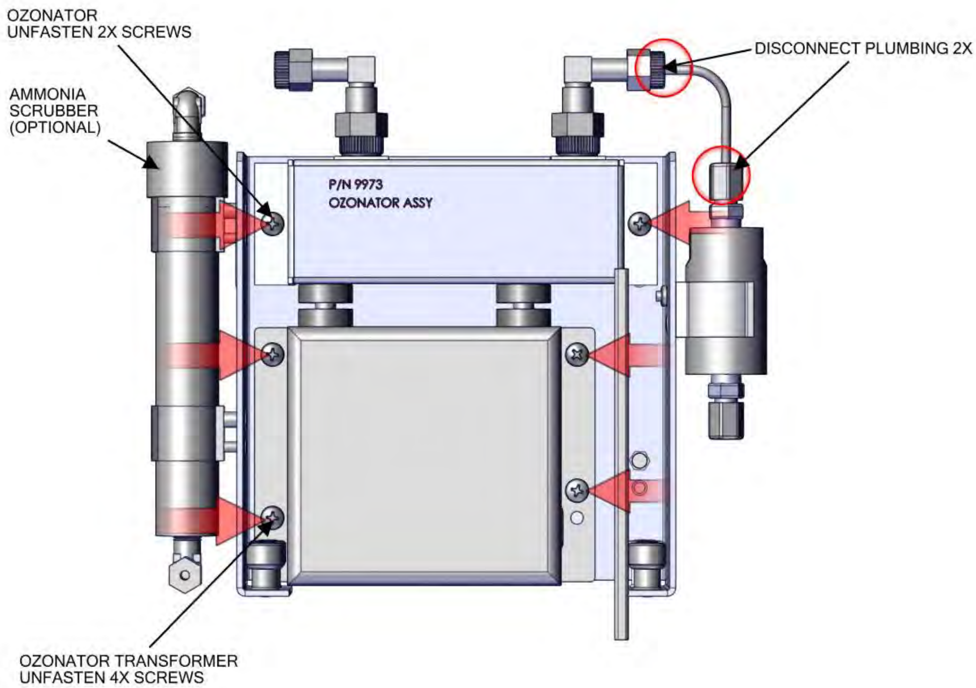


Figure 7–50. Replace Transformer

Ozonator and Transformer Board Replacement

Use the following procedure to replace the ozonator and transformer board.

Equipment Required:

Phillips drive, #2

1. Remove DMC Ozonator as described in "DMC Ozonator" in this chapter.

2. Unplug all electrical from HPVS board, ozonator (J1), flow switch (J5) converter DMC (J2) and flow pressure board (J4).

3. Using a #2 Phillips drive, unfasten four #6-32 pan head screws.

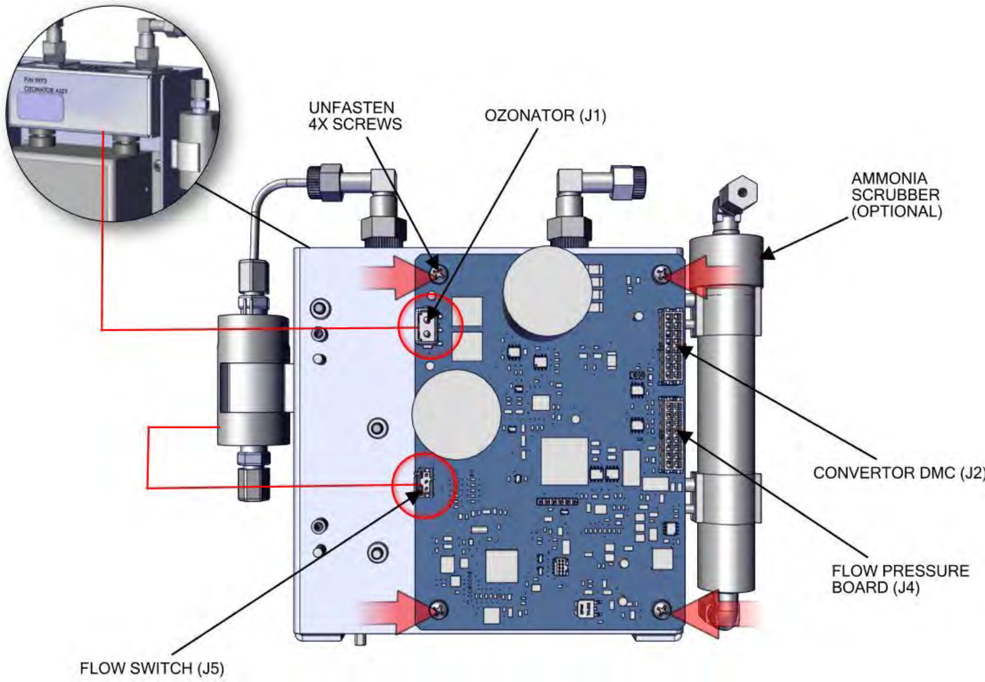


Figure 7–51. HPVS Remove Bd

Flow Switch Replacement

Use the following procedure to replace the flow switch.

Equipment Required:

Phillips drive, #2

1. Remove Ozonator as described in "DMC Ozonator" in this chapter.

2. Unplug flow switch (J5) from board.

3. Pull flow switch off clip after unplugging from board.

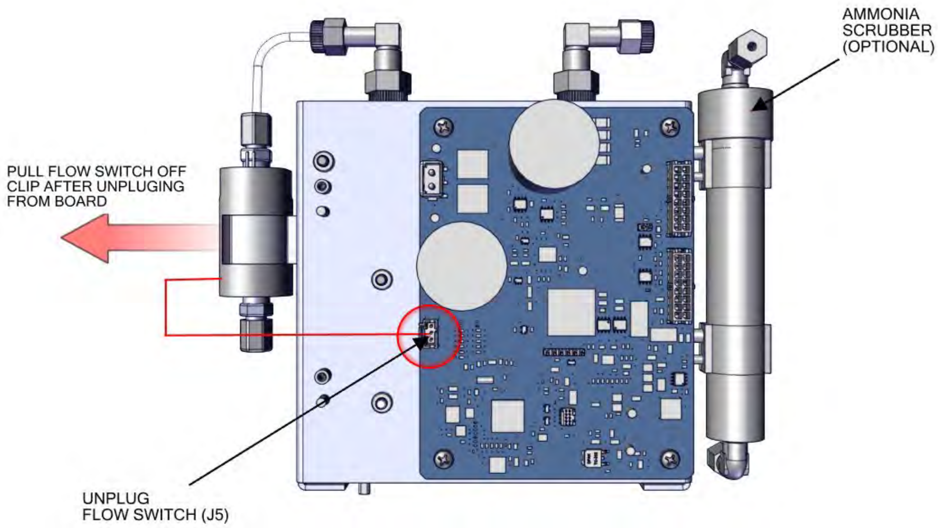


Figure 7–52. Flow Switch Remove

Optional Ammonia Scrubber Replacement

Use the following procedure to replace the optional ammonia scrubber.

Equipment Required:

Phillips drive, #2

1. Remove DMC Ozonator as described in "DMC Ozonator" in this chapter.

2. Disconnect plumbing 2X.

3. Pull Ammonia scrubber off clips 2X.

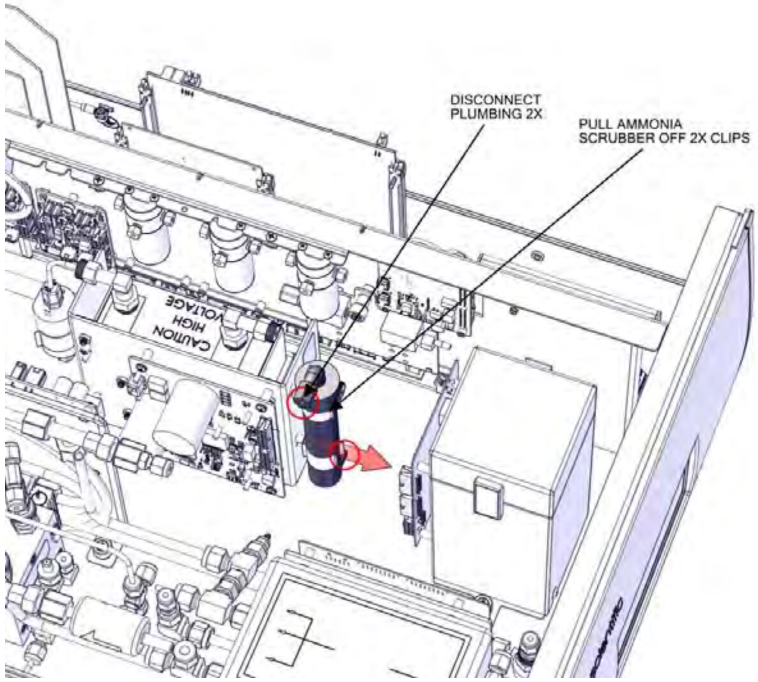


Figure 7–53. Remove Ammonia Scrubber

Optional Manifold Replacement

Use the following procedure to replace the manifold.

Equipment required:

Hex wrench, 9/16

Hex drive, 9/64

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

2. Unplug three electrical connections (J5, J6, and J8) from the step pol board 1.

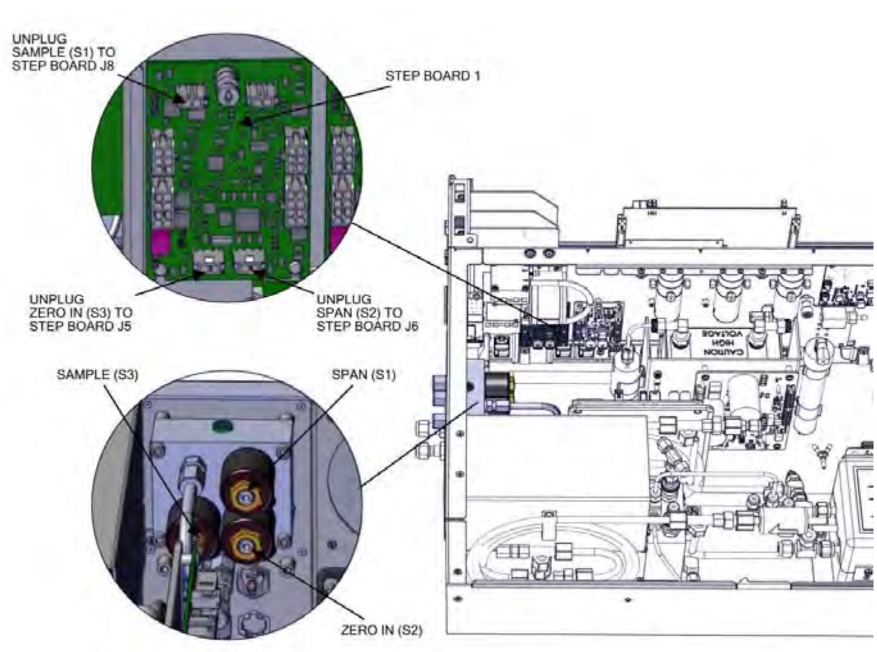


Figure 7–54. Replacing the Manifold pt 1

3. Unfasten three nuts. Remove the nuts, front and back ferrules as shown from span, zero in, sample back panel (Figure 7–55).

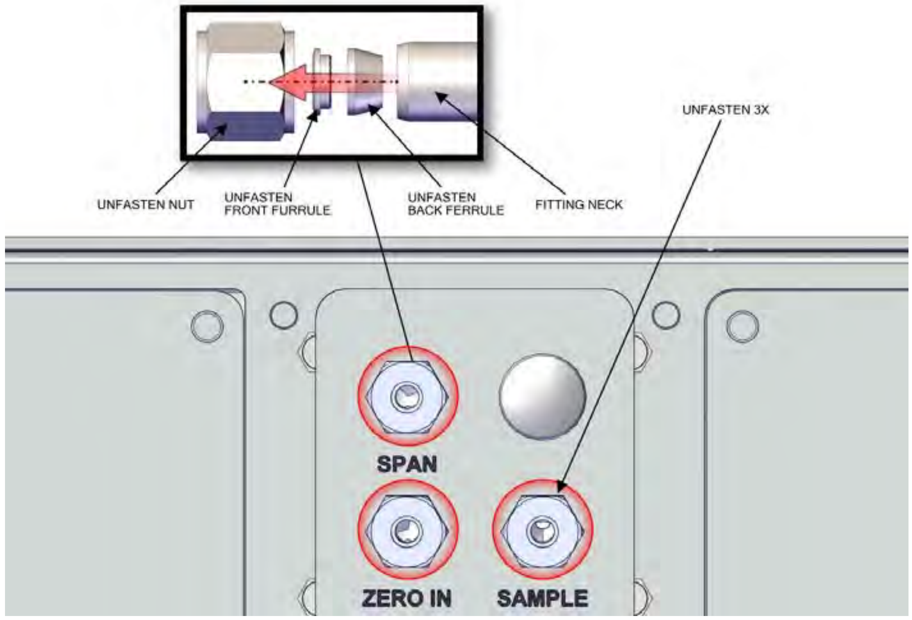


Figure 7–55. Replacing the Manifold pt 2

4. Disconnect tubing.

5. Using a #2 Phillips drive, unfasten four #8-32 socket cap head screws.

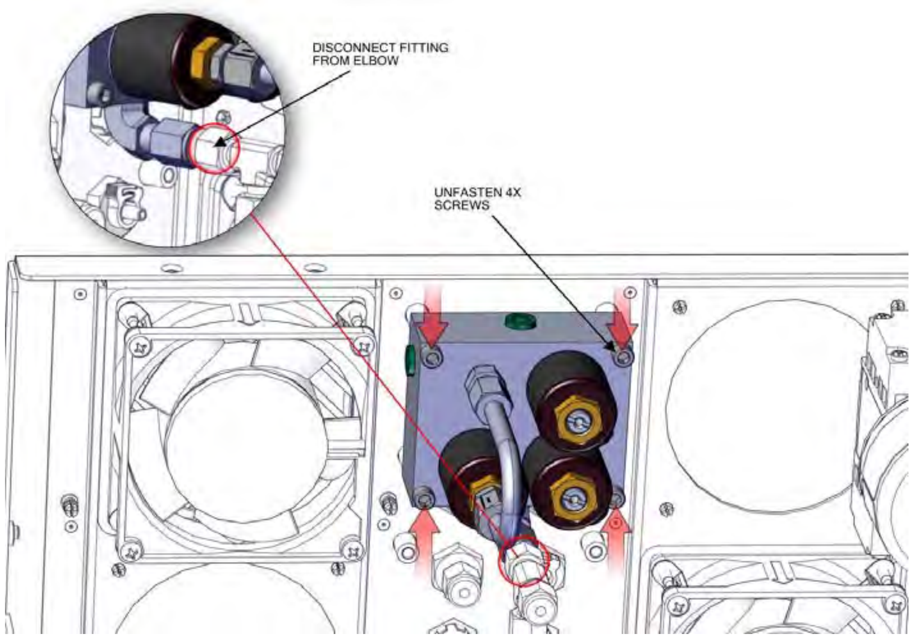


Figure 7–56. Replacing the Manifold pt 3

6. Replace the manifold and assemble in reverse order.

Optional Solenoid Valves Removal

Use the following procedure to replace the mode valve, and optional permeation oven valve and lag valve.

Equipment Required:

Phillips drive, #1

CAUTION Allow the oven to cool down prior to servicing. ▲

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

2. Unplug mode valve (J5), lag valve (J6), and perm valve (J7) from step board 2 only.

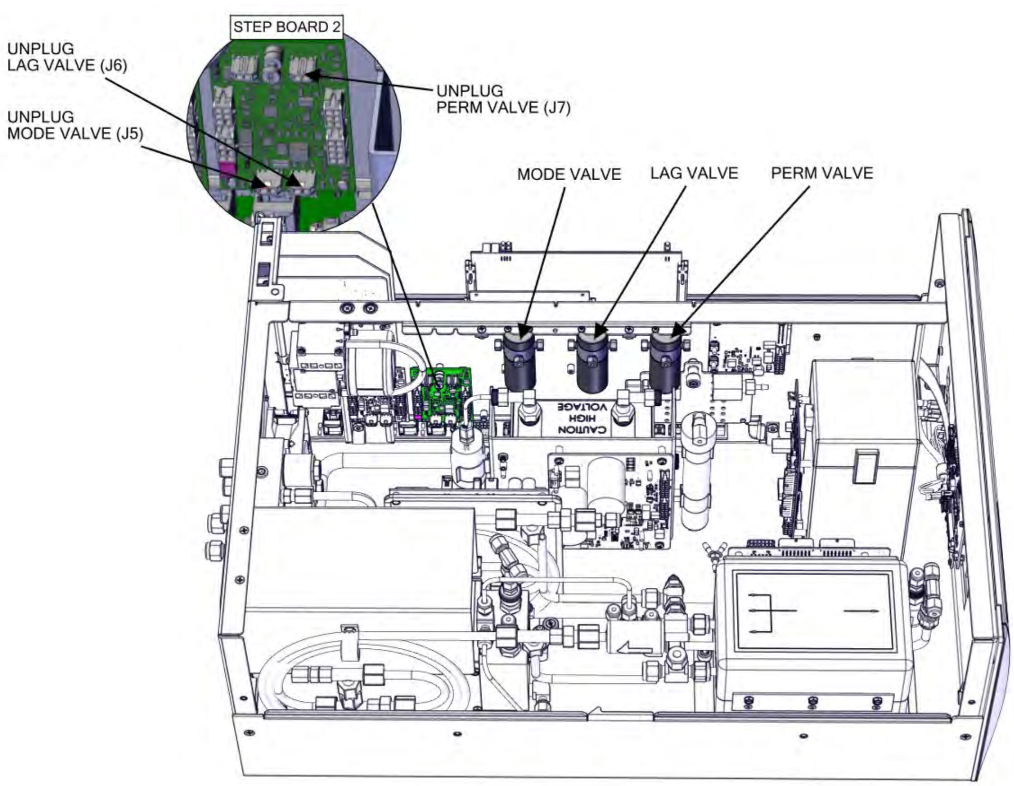


Figure 7–57. Mode-Lag-Perm Electrical Connection

3. Using a #1 Phillips drive, loosen two #4-40 pan head screws.

4. Slide valve out.

Equipment Damage Do not disconnect the plumbing from the valve end. Disconnect from the attaching end only. This will prevent damaging and leaks from the valve end. ▲

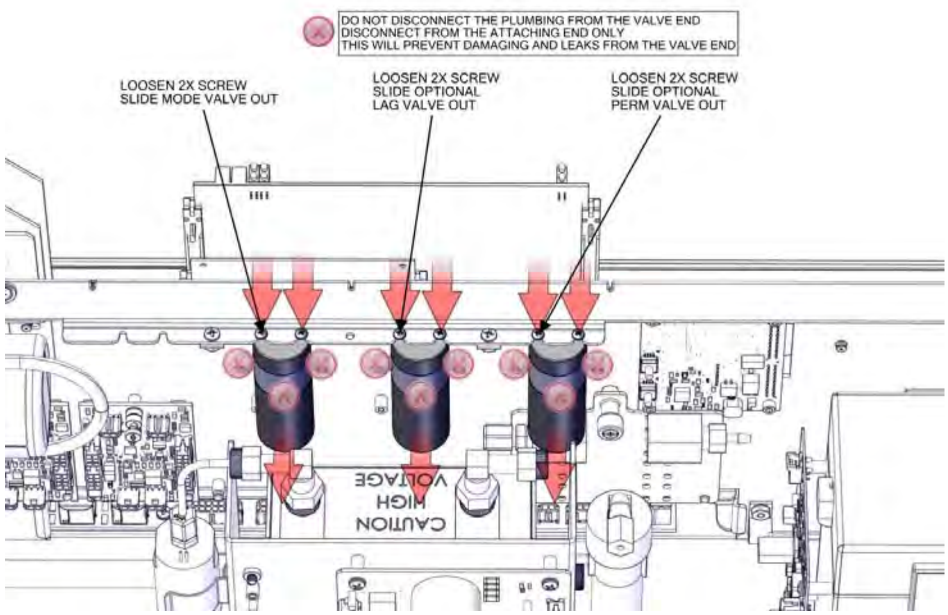


Figure 7–58. Mode-Lag-Perm Hardware, Plumbing

Permeation Oven Replacement

Use the following procedure to replace the permeation oven.

Equipment required:

Phillips drive, #2

Tube release tool (optional)

CAUTION Allow oven to cool down prior to servicing. ▲

1. Turn the instrument OFF, unplug the power cord, and remove the cover (Figure 2–1).

2. Unplug DMC cables as shown.

3. Disconnect plumbing.

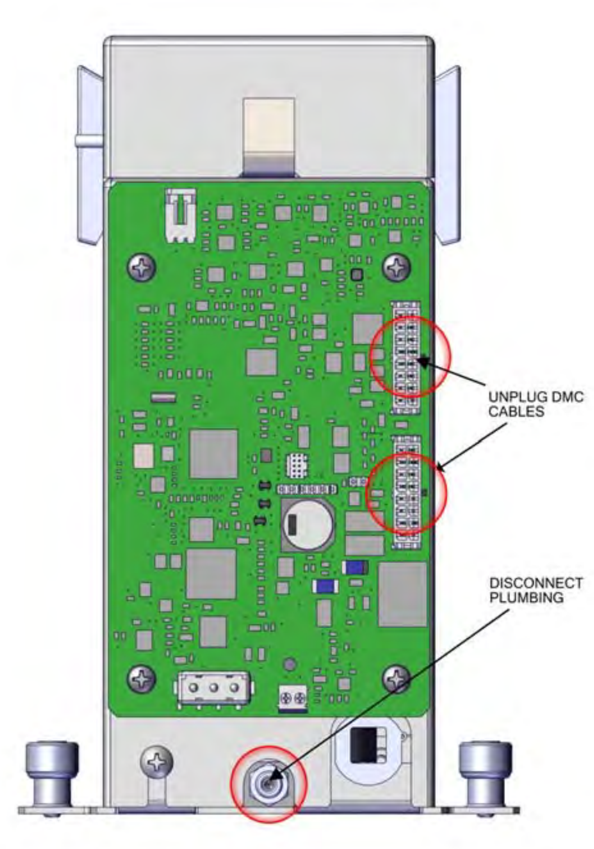


Figure 7–59. Perm Oven pt 1

4. Push in fitting head evenly with fingers towards fitting body.

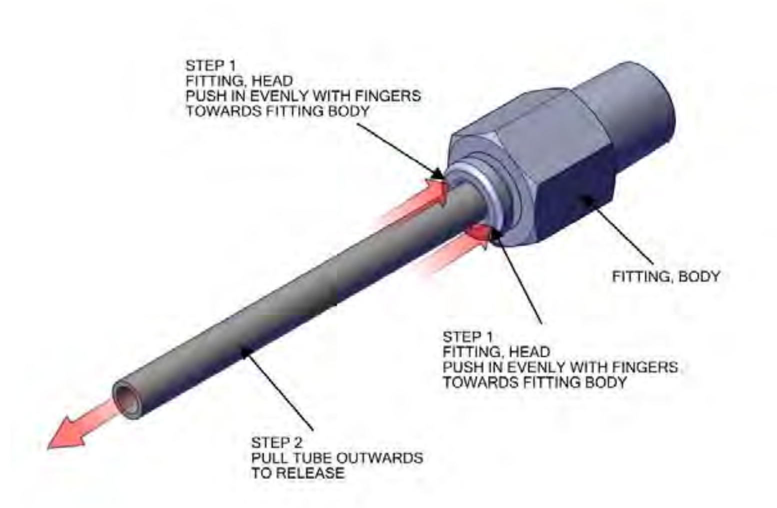
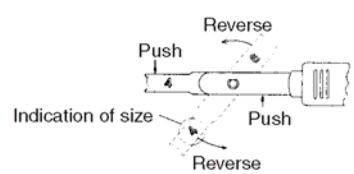


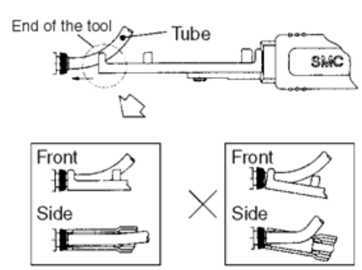
Figure 7–60. Finger Push and Release Tubing

5. Pull tube outwards to release. If using the tool provided:

   a. Adjust tool size to 1/4 tube as indicated on the back side.



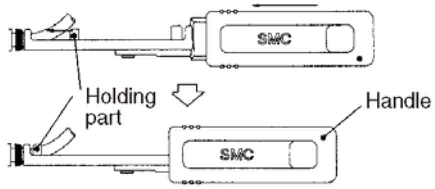
   b. Tool edge should be pushed straightforward into the edge of the release button along with the tube in the axial fitting direction.



   c. After inserting, grasp handle tightly and insert the end of the tubing to the stroke end.

   Note Insert firmly to the guard against an accidental tube release. ▲

   d. After inserting end of tube, relax your grip on the tool. Returning force of spring releases the tube.



Push both sides at once to release. Reverse and fix at the same position as before. Applicable tube size is indicated on the back side.

6. Disconnect plumbing from inline fitting.

Note Do not disconnect from valve end. ▲

7. Unfasten two captive hardware.

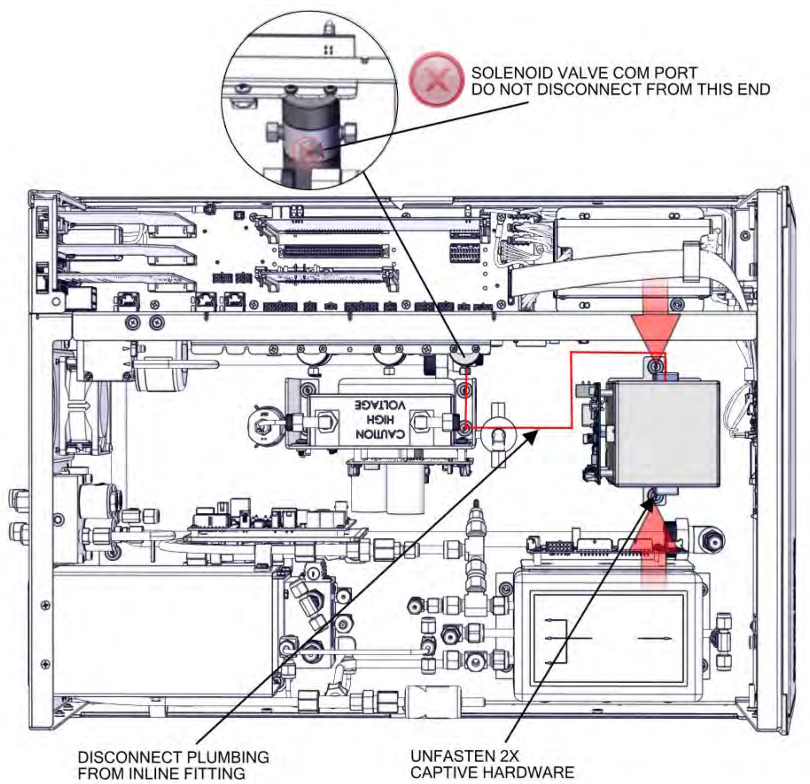


Figure 7–61. Perm Oven Replacement pt 2

8. Replace DMC permeation oven and assembly in reverse order.

Permeation Oven Board Replacement

Use the following procedure to replace the permeation oven board.

Equipment required:

Phillips drive, #2

CAUTION Allow oven to cool down prior to servicing. ▲

1. Turn instrument OFF, unplug power cord, and remove the cover (Figure 2–1).

2. Unplug all electrical J1, J7, J8, J9 as shown.

3. Using #2 Phillips drive, unfasten four 6-32 pan head screws.

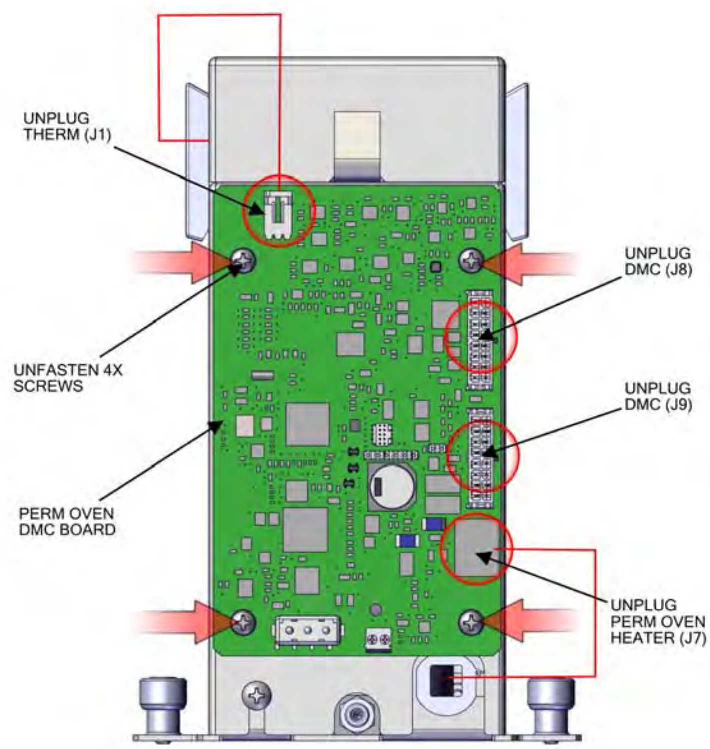


Figure 7–62. Replacing the Permeation Oven Board

4. Replace permeation board and assemble in reverse order.

Chapter 8
System Description

The 42iQ deploys a set of modular subsystems that comprise the total instrument function. The core measurements for concentration are contained in Distributed Measurement and Control (DMC) modules. This chapter describes the function and location of the system components in the module framework, including firmware, electronics, and I/O function.

The 42iQ system components include:

- Reaction Chamber DMC
  - Optical filter
  - Photomultiplier tube (PMT)
  - Photomultiplier tube cooler
- Ozonator DMC
  - Ozonator DMC board
  - Ozone flow switch
- Ozonator Permeation Dryer
- NO_2-to-NO converter DMC
  - Converter DMC board
- Permeation Oven (optional)
- Common Electronics
  - Power supply
  - System Control board
  - Backplane board
  - Front panel
  - I/O (optional)
- Peripherals Support System
  - Fan (on rear panel)
  - STEP POL board

  - Sample pump
  - Mode Solenoid
  - Solenoid valve panel (optional)
- Flow Pressure DMC with restricting capillary
- Firmware

Reaction Chamber DMC

The reaction chamber is where the sample reacts with ozone and produces excited NO_2 that gives off a photon of energy when it decays.

The reaction chamber is heated and controlled to approximately 50 °C in order to ensure the greatest instrument stability. The sample and ozone flow capillaries and a thermistor sensor are also housed in/on the reaction chamber assembly.

Optical Filter

The optical filter housed in the reaction chamber limits the spectral region viewed by the detector and eliminates possible interferences due to other chemiluminescent reactions.

Photomultiplier Tube

The Photomultiplier tube (PMT) provides the infrared sensitivity required to detect the NO_2 luminescence resulting from the reaction of the ozone with the ambient air sample.

Optical energy from the reaction is converted to an electrical signal by the PMT and sent to the input board that transmits it to the processor.

Photomultiplier Tube Cooler

The thermoelectric PMT cooler reduces the PMT temperature to approximately -3 °C to minimize dark current and increase instrument sensitivity. The cooler helps to increase zero and span stability over a wide ambient temperature range. The cooler housing also shields the PMT from external electrical and optical interferences.

Ozonator

The Ozonator generates the necessary ozone concentration required for the chemiluminescent reaction. The ozone reacts with the NO in the ambient air sample to produce the electronically excited NO_2 molecules.

Ozonator Flow Switch

The ozonator flow switch located at the ozonator inlet completes an electrical safety circuit when air flows through the sensor to the ozonator. If airflow stops, the flow sensor breaks the electrical circuit to the ozonator and shuts it off to prevent the ozonator from overheating.

Ozonator Permeation Dryer

The permeation dryer minimizes routing maintenance procedures by providing a continuous stream of dry air to the ozonator (using the selective water permeation characteristics of the dryer). With the permeation dryer option, it is not necessary to constantly replenish the ozonator air-drying column as in the standard instrument.

NO_2-to-NO Converter

The NO_2-to-NO converter heats molybdenum to approximately 325 °C in order to convert and detect NO_2. The converter consists of an insulated housing, heater, replaceable cartridge, and a type K thermocouple sensor.

Permeation Oven (Optional)

The 42iQ can be configured with an optional permeation oven for generating NO_2 span gas. The permeation oven is configured as a DMC module with self-contained temperature measurements and heater controls. For more information, see "Internal Permeation Span Source" as described in Chapter 9, "Optional Equipment".

Common Electronics

The common electronics contain the core computational and power routing hardware for the 42iQ, and is replicated throughout other iQ series products (Figure 8–1). It also contains front panel display, the USB ports, the Ethernet port, and the optional I/O interfaces (RS-485, analog, and digital).

Figure 8–2 shows the PCBA interconnect structure for the 42iQ, including options. The modular design of the instrument is conveyed in the architecture. Brief descriptions of the specific PCBAs follow.

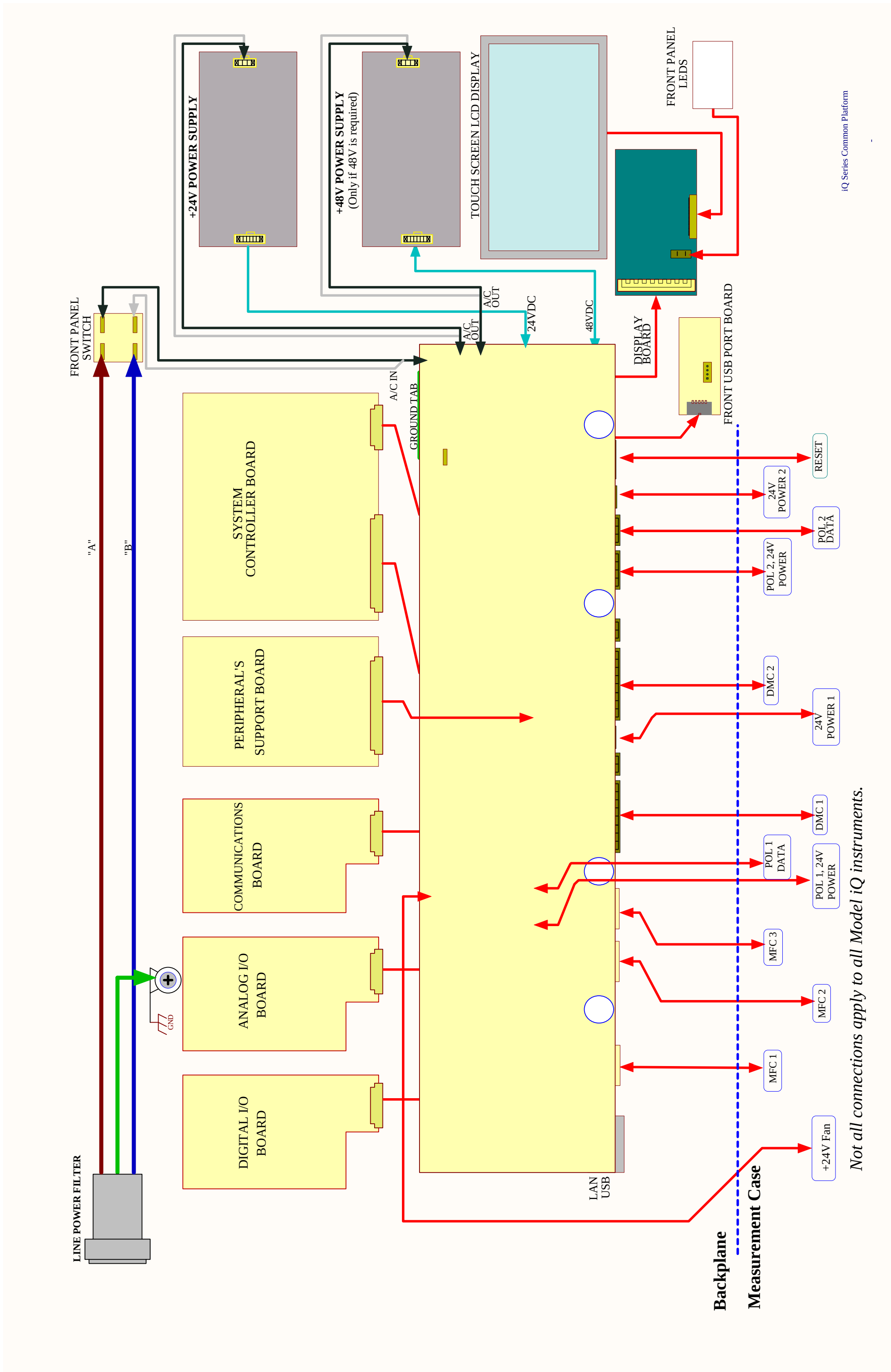


Figure 8–1. Common System Interconnect Diagram

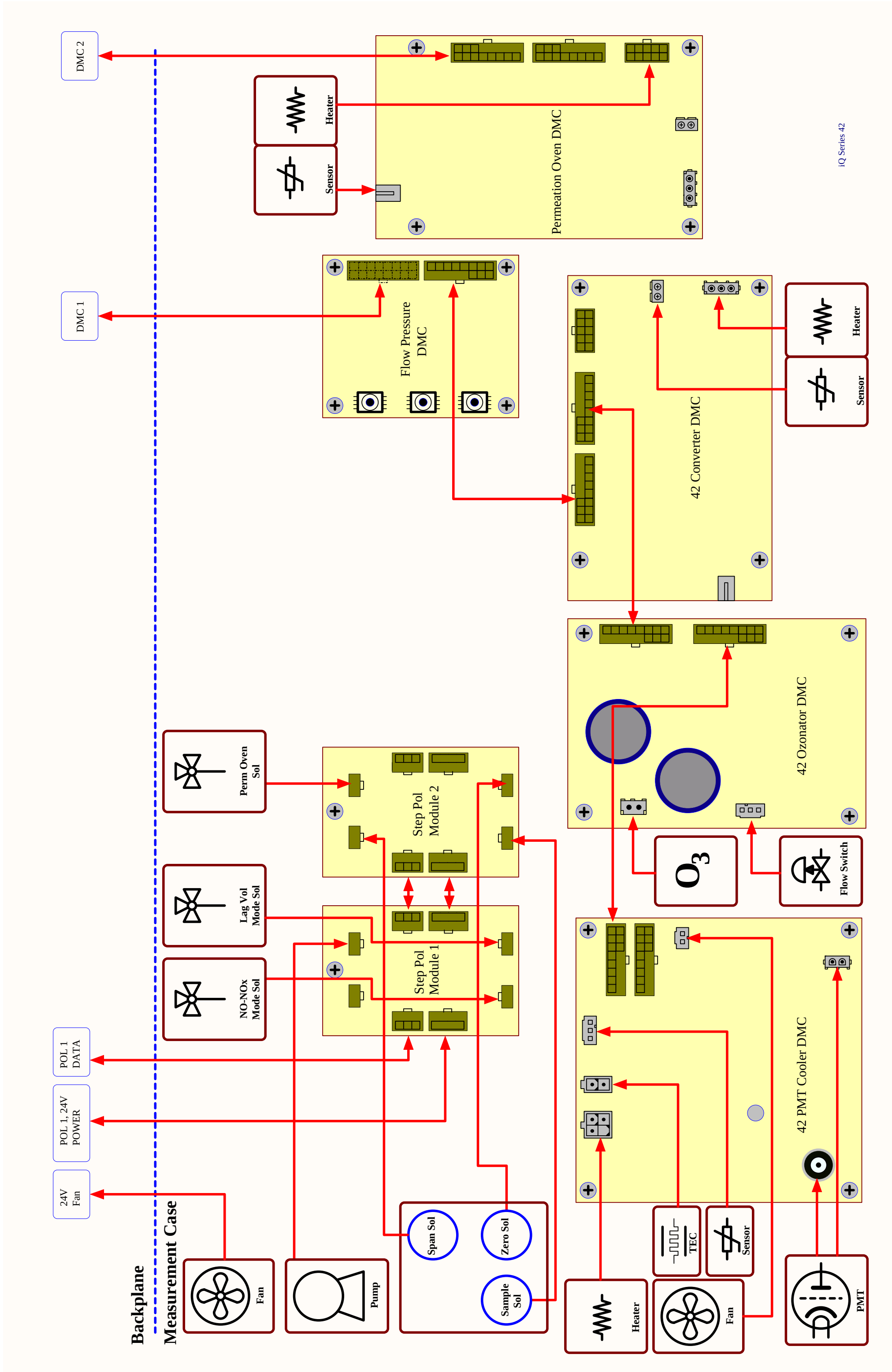


Figure 8–2. 42iQ System Interconnect Diagram

Power Supply

All electronics operate from a universal VDC supply, which is capable of auto-sensing the input voltage and working over all specified operating ranges. The 42iQ contains a 24 VDC channel for most electronics operation, including the pump and fan, and a 48 VDC channel dedicated specifically for optical bench heating.

Front Panel

Front panel electronic components include the touch screen display, the on off switch, and two indicator LEDs for power and alarm status, as described in operational detail in Chapter 2, "Installation and Setup".

I/O and Communication Components

The iQ series instruments provide a number of methods for communicating the instrument results to the operator or external equipment. Every iQ series instrument includes a front panel display, 3 USB ports, and one Ethernet data port as standard equipment.

In addition, optional RS-232/485, analog I/O, and digital I/O ports are available to provide data to external systems as described in Chapter 9, "Optional Equipment". The front panel GUI allows the operator to configure these output communication channels as described in Chapter 3, "Operation".

System Controller Board

The System Controller Board (SCB) contains the main processor, power supplies, and a sub-processor, and serves as the communication hub for the instrument. The SCB receives operator inputs from the front panel GUI and/or over optional I/O connections on the rear panel. The SCB sends commands to the other boards to control the functions of the instrument and to collect measurement and diagnostic information. The SCB outputs instrument status and measurement data to the GUI, Ethernet/USB, and to the optional rear-panel I/O. The SCB plugs into the backplane via a single connector and has physical retainers to secure placement.

Backplane Board

The backplane board provides the routing and conditioning for +24 VDC (optional +48 VDC) and RS-485 communications within the instrument. It hosts the System Controller Board (SCB) and Peripherals Support Board (PSB) via direct plug ins, and similarly hosts optional I/O (communication, analog, and digital) with rear panel interfaces via direct plug in. It has connections for RS-485 communication with and powering of DMCs and the STEP POL Module. It additionally routes the front panel display and driver, external USB and Ethernet.

Peripherals Support System

The peripherals support system operates these additional devices that are needed, but do not require special feedback control or processing. These components are connected to a Peripherals Support Board (PSB).

Fan

The chassis fan provides air cooling of the active electronic components.

STEP POL Board

The STEP POL board provides high/low outputs for continuous operation or on/off states. The STEP POL board contains the basic circuitry to provide a programmable load to passive devices, either continuously, or on user or automated command. In the iQ Series instruments, the pump, solenoids, etc., are controlled off of the STEP POL board from commands generated via the PSB.

Sample Pump

Internal vacuum pump for generating air/sample through the instrument.

Mode Solenoid

The mode solenoid valve switches analyzer operation between the NO mode and NO_x mode. It routes the ambient air sample either through the reaction chamber (NO mode) or through the NO_2-to-NO converter and then to the reaction chamber (NO_x mode).

Solenoid Valve Panel

Optional solenoid valves for switching between sample, zero, and span gases, and other optional components.

Flow/Pressure DMC

The flow pressure DMC performs the pressure measurements that assure proper flow regulation, and also for the sample pressure within the reaction chamber. It is coupled with a standard restricting capillary for flow when the downstream pump is operating: Upstream pressure is ambient, while downstream pressure allows determination of flow. A single PCBA with microprocessor provides the active controls for the pressure measurements, performs flow determination, and generates registers that interact with the higher level system controls.

Firmware

Like the hardware, the firmware is modular and located within microprocessors distributed throughout the instrument. In the 42iQ, microprocessors containing firmware are located as follows:

- Reaction Chamber/PMT DMC
- Ozonator DMC
- NO_2 Converter
- Flow/Pressure DMC
- Peripherals Support Board
- Optional I/O (Communications, Digital, and Analog)

The firmware contains the active controls for their application, as well as self-identification and configuration for "plug and play" style operation. Each are associated with specific registers of two types:

- Modbus registers that are communicated from each microprocessor to the System Controller Board (SCB) via internal RS-485
- SNMP registers that are maintained in the software and SCB for health and data processing computation

The Modbus communication system operates on 1 second intervals. Within those intervals, data treatment like integration (whether analog or digital) and servo control, are embedded in the module firmware. The SCB receives the 1 second updates for higher level "software" processing and control via SNMP registers, some of which is interfaced with the front panel Graphical User Interface (GUI).

In addition to the operating registers, the 42iQ stores a historical data log in a MySQL database. The memory is provided on the same uSD card where the operating software resides, for which there is capability to store up to a year of data at 1 minute intervals. Chapter 3, "Operation" describes how this database is accessed and used including external memory downloads.

Chapter 9
Optional Equipment

The 42iQ is available with the following options:

Connecting External Devices

Several components are available for connecting external devices. These connection options consist of three plug-in boards:

- Communication Board
- Analog I/O Board
- Digital I/O Board

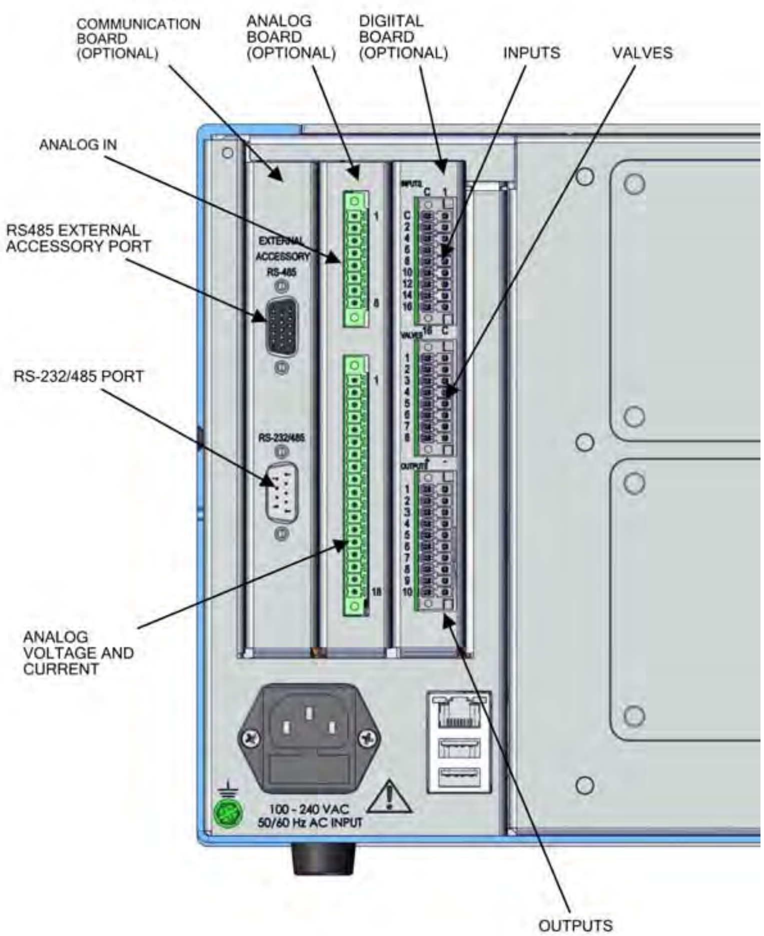


Figure 9–1. I/O Expansion Replacement Boards

Communication Board

The communication board consists of:

- RS-232/485 Port
- RS-485 External Accessory Port

RS-232/RS-485 Port

The RS-232/RS-485 port uses a 9-pin serial connector with a bi-directional serial interface that can be configured for either RS-232 or RS-485 communication.

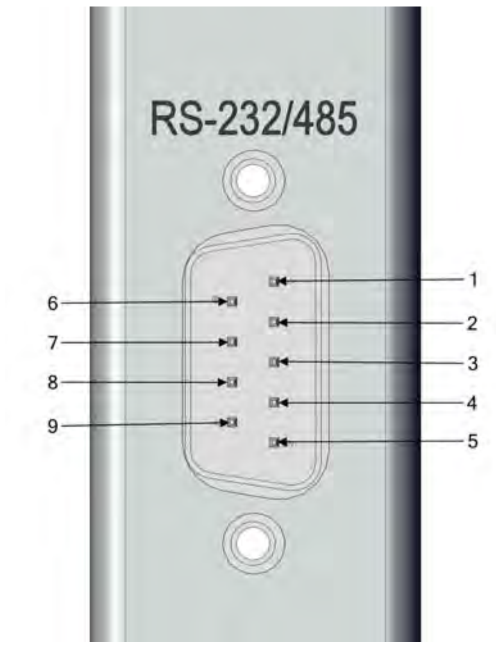


Figure 9–2. RS-232/RS-485 Port

Table 9–1. RS-232/RS-485 Port Terminal Assignment

Terminal Number	Signal Name
1	No Connect
2	RX/RS485_RX_P
3	TX/RS485_TX_N
4	No Connect
5	GND
6	No Connect
7	RTS/RS485_TX_P
8	CTS/RS485_RX_N
9	No Connect

RS-485 External Accessory Port

The RS-485 external accessory port uses a 15-pin serial connector for communication with external smart devices.

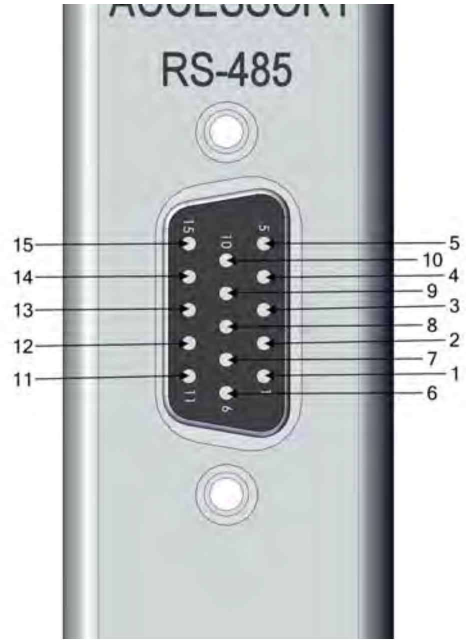


Figure 9–3. RS-485 External Accessory Port

Table 9–2. RS-485 External Accessory Port Terminal Assignment

Terminal Number	Signal Name
1	EXT_RS485_RX_N
2	EXT_RS485_RX_P
3	+5V (Fused @0.4A)
4	+5V (Fused @0.4A)
5	+5V (Fused @0.4A)
6	GND
7	GND
8	GND
9	EXT_RS485_TX_N
10	EXT_RS485_TX_P
11	+24V (Fused @0.4A)
12	+24V (Fused @0.4A)
13	+24V (Fused @0.4A)
14	+24V (Fused @0.4A)
15	+24V (Fused @0.4A)

Analog I/O Board

The Analog I/O Board consists of:

- 4 Isolated Analog Voltage Inputs, Input Voltage Range: 0–10 V
- 6 Isolated Analog Voltage Outputs, Three Ranges: 0–1.0 V, 0–5.0 V, 0–10 V
- 6 Isolated Analog Current Outputs, Two Ranges: 0mA–20mA, 4mA–20mA

Analog Voltage Inputs

Table 9–3 lists the analog voltage inputs are used to monitor four external 0–10V signals.

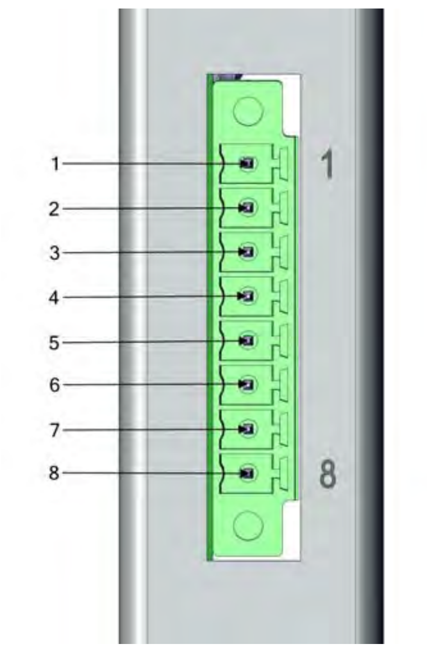


Figure 9–4. Analog Voltage Inputs

Table 9–3. Analog Voltage Inputs Assignment

Terminal Number	Signal Name
1	Analog In 1
2	Analog GND
3	Analog In 2
4	Analog GND
5	Analog In 3
6	Analog GND
7	Analog In 4
8	Analog GND

Analog Voltage Outputs

There are six globally isolated, 16-bit, Analog Output channels, each with a Voltage Output, a Current Output and a common Return (isolated ground). The Analog Outputs are configured through the software control registers to select Voltage Output ranges 0–1 V, 0–5 V or 0–10 V, as well as Current Output ranges 0–20 mA or 4–20 mA. The maximum allowable load for each Current Output is 1000 Ω. All Voltage Outputs and Current Outputs are continuously monitored separately for accuracy.

The Analog Outputs may be used to control and report parameters pertinent to the analyzers' measured functions.

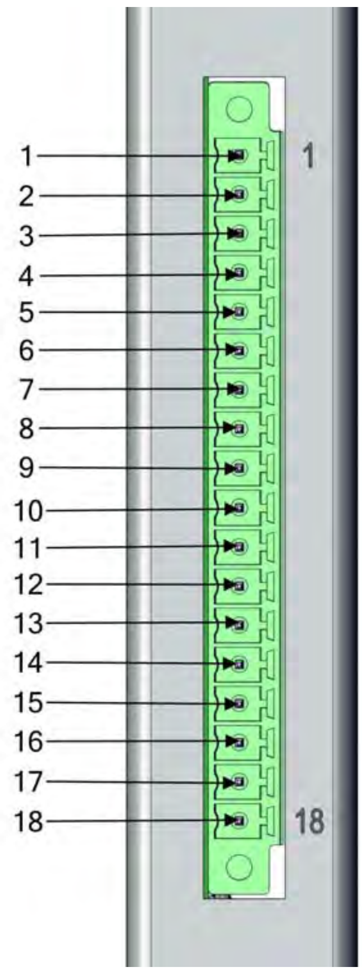


Figure 9–5. Analog Voltage and Current

Table 9–4. Analog Voltage and Current Assignment

Terminal Number	Signal Name
1	Current Out 1
2	Voltage Out 1
3	C/V Return 1
4	Current Out 2
5	Voltage Out 2
6	C/V Return 2
7	Current Out 3
8	Voltage Out 3
9	C/V Return 3
10	Current Out 4
11	Voltage Out 4
12	C/V Return 4
13	Current Out 5
14	Voltage Out 5
15	C/V Return 5
16	Current Out 6
17	Voltage Out 6
18	C/V Return 6

Analog Output Calibration

The iQ series instruments provide for the ability to calibrate the analog outputs (both voltage and current) of the instruments. The basic procedure for both voltage and current are the same using the following procedure:

- Complete the connections of the recording device to the desired analog output channel. (See page 9-5 for the channel information).
- Calibrate the output channel low level.

  Note When calibrating the current output when using the 0-20 mA scale, the low level will be set to 4 mA due to the inability to adjust the actual current output to below zero. ▲

- Calibrate the output channel full scale.

Analog Output Zero Calibration

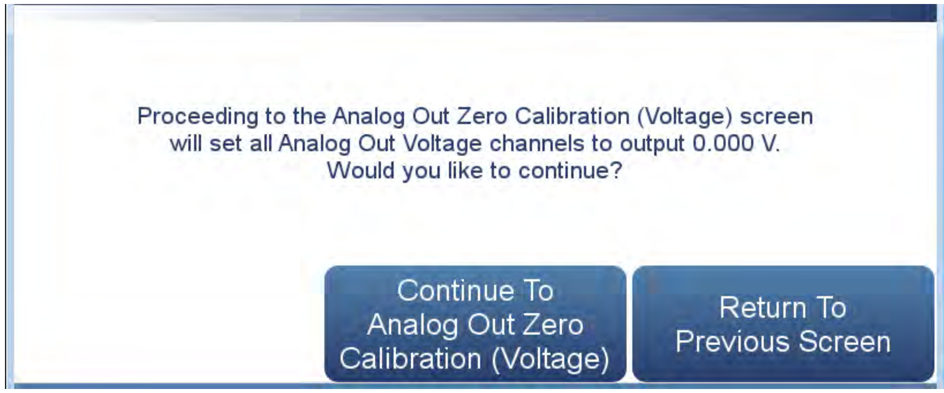
Use the following procedure to calibrate the output channel to low level. This analog output calibration procedure reflects the zero calibration for analog output voltage for demonstration purposes. To calibrate the 4 mA current calibration, follow the same procedure, by selecting the 4 mA current calibration option.

Note This adjustment should only be performed by an instrument service technician. ▲

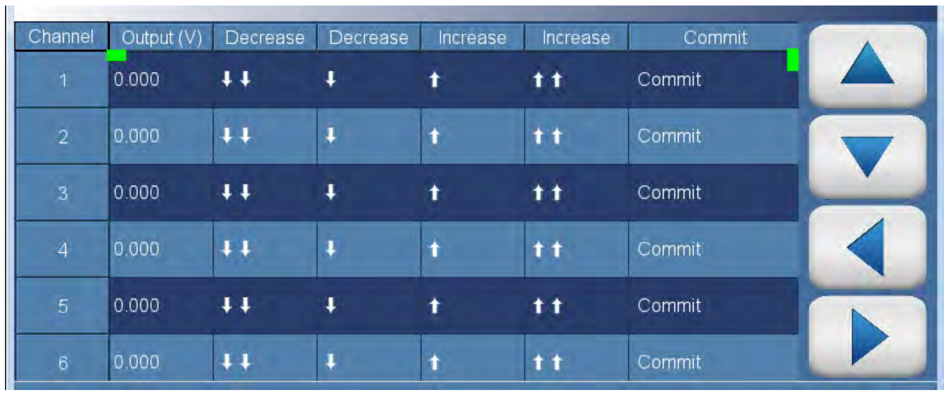
1. From the Home screen, choose **Settings>Communications>Analog I/O>Analog Out Calibration.**

2. Depending on the output type being used, select either Analog Out Zero Calibration (Voltage) or Analog Out 4.000 mA Calibration (Current).

3. A confirmation screen is presented. Select Continue to proceed with the calibration or Return to Previous Screen.



4. There are six columns for each of the six available output channels:



- *Output (V):* Displays the actual output level at the terminal of the analog output board. For analog voltage, this value will default at zero. For analog current, this value will default at 4 mA.
- *Decrease* ↓↓ *and Decrease* ↓*:* Decreases the output by coarse or fine amounts
- *Increase* ↑ *and Increase* ↑↑*:* Increases the output by coarse and fine amounts.
- *Commit:* Accepts the changes to the analog output levels.

5. For the desired analog output channel, increase or decrease the output until the reading on the recording device indicates the proper value.

6. After making changes to the output levels, the commit button will turn green. To accept the changes, press the Commit button. To revert to the previous values, press the back button to return to the previous analog output calibration screen.

Analog Output Full Scale Calibration

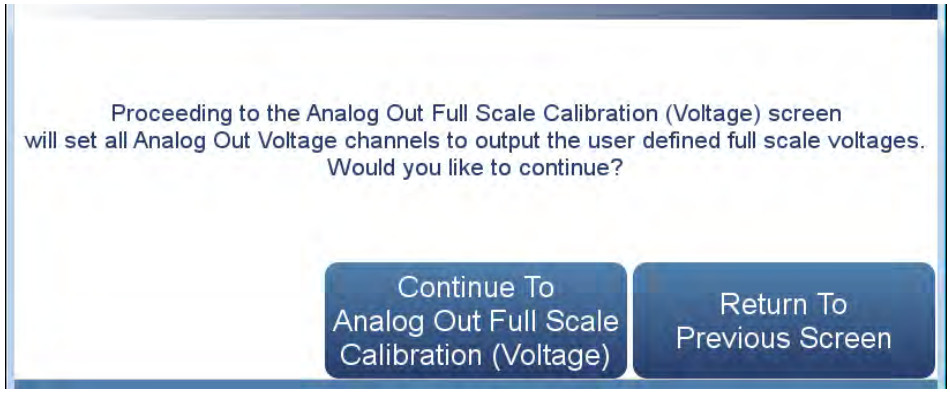
Use the following procedure to calibrate the output channel to full scale. This analog output calibration procedure reflects the full scale calibration for analog output voltage for demonstration purposes. To calibrate the 20 mA current calibration, follow the same procedure, by selecting the 20 mA current calibration option.

Note This adjustment should only be performed by an instrument service technician. ▲

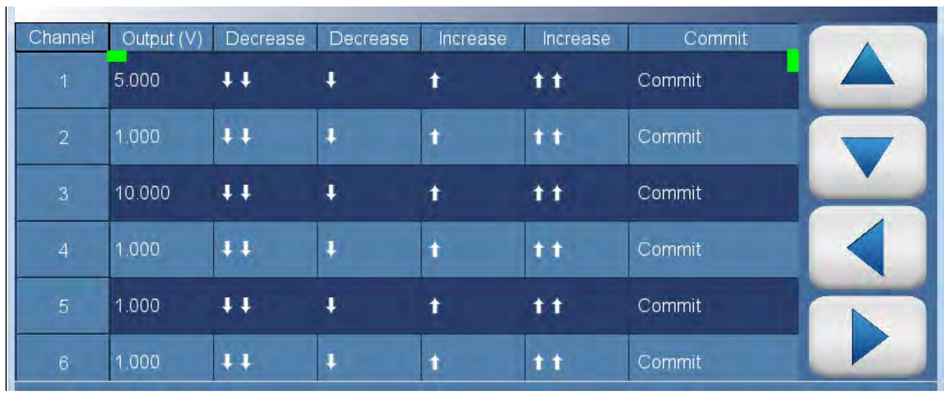
1. From the Home screen, choose **Settings>Communications>Analog I/O>Analog Output Calibration.**

2. Depending on the output type being used, select either Analog Out Full Scale Calibration (Voltage) or Analog Out 20.000 mA Calibration (Current).

3. A confirmation screen is presented. Select Continue to proceed with the calibration or Return to Previous Screen.



4. There are six columns for each of the six available output channels:



- *Output (V):* Displays the actual output level at the terminal of the analog output board. For analog voltage, this value will default at the setting of the output channel, 1, 5, or 10 V. For analog current, this value will default at 20 mA.
- *Decrease* ↓↓ *and Decrease* ↓*:* Decreases the output by coarse or fine amounts
- *Increase* ↑ *and Increase* ↑↑*:* Increases the output by coarse and fine amounts.
- *Commit:* Accepts the changes to the analog output levels.

5. For the desired analog output channel, increase or decrease the output until the reading on the recording device indicates the proper value.

6. After making changes to the output levels, the commit button will turn green. To accept the changes, press the Commit button. To revert to the previous values, press the back button to return to the previous analog output calibration screen.

Digital I/O Board

The digital I/O board consists of:

- 16 Digital Inputs (18 pin connector)
- 10 Digital Relay Switches (20 pin connector)
- 8 Valve Driver Outputs (16 pin connector)

Digital Inputs

The digital inputs are TTL (3 V or 5 V) compatible and are pulled high within the instrument. The active state can be user defined in firmware.

- Logic Low Threshold: 0.8 V
- Logic High Threshold: 2.0 V
- Absolute allowable input voltages: -0.5 to 5.5 V

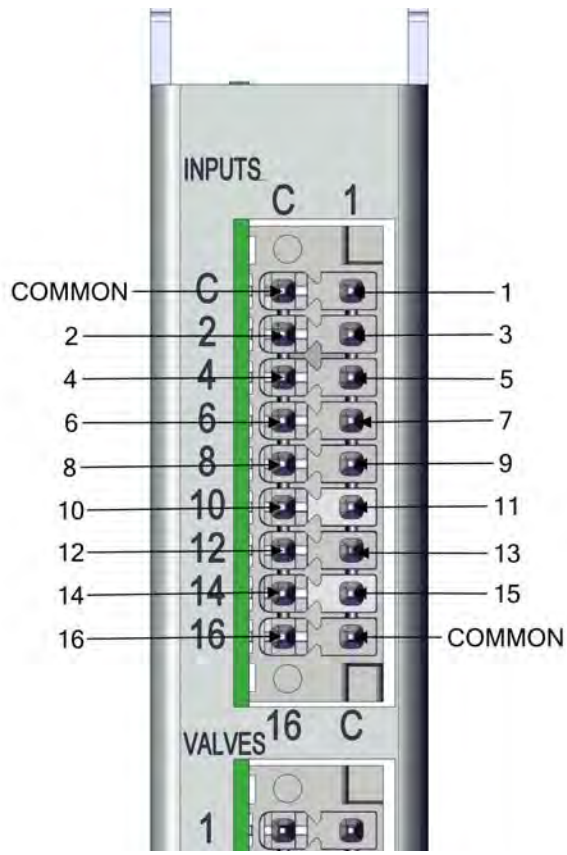


Figure 9–6. Digital Inputs

Table 9–5. Digital Inputs Terminal Assignment

Terminal Number	Signal Name
COMMON	
1	Digital In 1
2	Digital In 2
3	Digital In 3
4	Digital In 4
5	Digital In 5
6	Digital In 6
7	Digital In 7
8	Digital In 8
9	Digital In 9
10	Digital In 10
11	Digital In 11
12	Digital In 12
13	Digital In 13
14	Digital In 14
15	Digital In 15
16	Digital In 16
COMMON	

Digital Relay Switches

Table 9–6 lists the digital relay switches.

- Maximum Voltage: 300 VDC
- Maximum Current: 500 mA
- Fuse: 800 mA

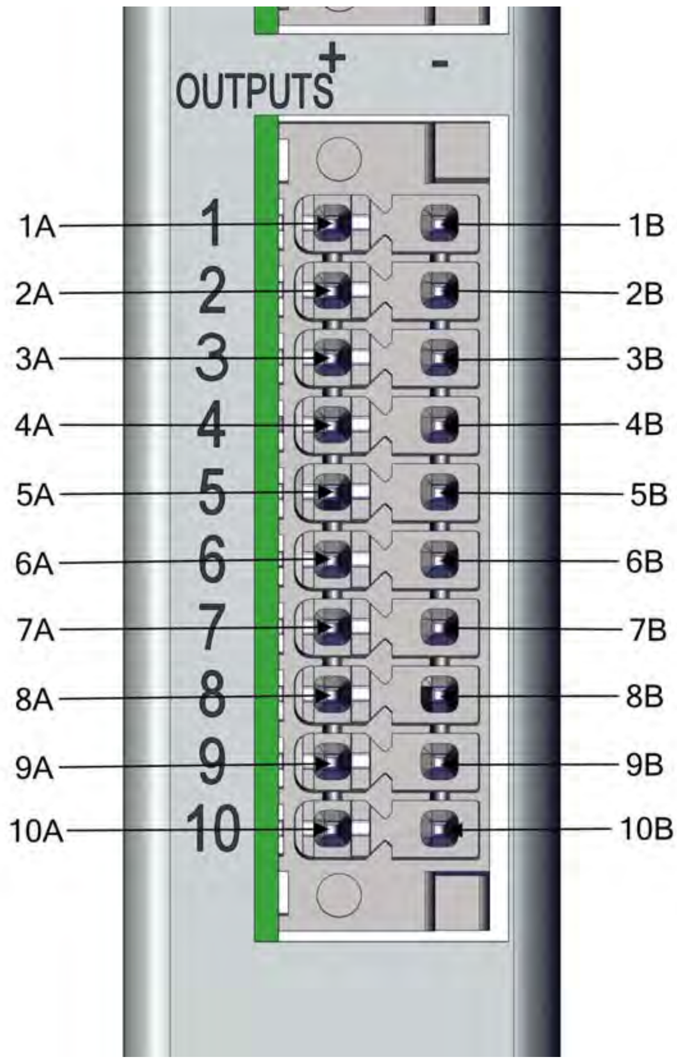


Figure 9–7. Digital Relay Switches

Table 9–6. Digital Relay Switch Assignment

Terminal Number	Signal Name
1A	Relay 1A
1B	Relay 1B
2A	Relay 2A
2B	Relay 2B
3A	Relay 3A
3B	Relay 3B
4A	Relay 4A
4B	Relay 4B
5A	Relay 5A
5B	Relay 5B
6A	Relay 6A
6B	Relay 6B
7A	Relay 7A
7B	Relay 7B
8A	Relay 8A
8B	Relay 8B
9A	Relay 9A
9B	Relay 9B
10A	Relay 10A
10B	Relay 10B

Valve Driver Outputs

Table 9–7 lists the valve driver outputs.

- Actual Output Voltage: 22–24 VDC
- Maximum Current: 300 mA
- Both positive and negative outputs are protected from over voltage and over current by 500 mA fuses.

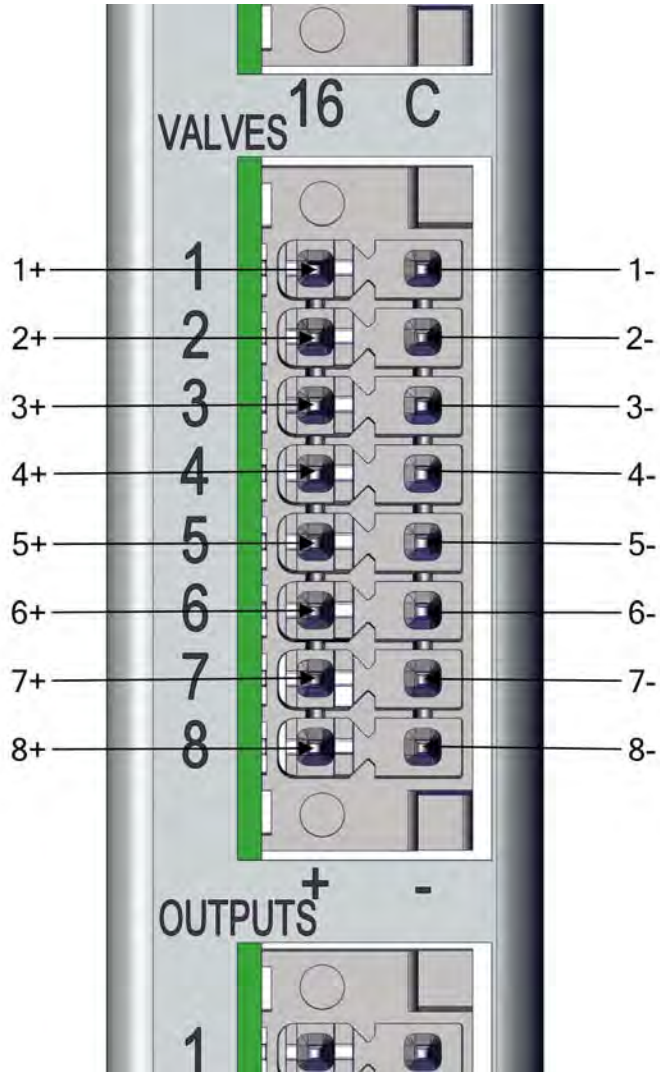


Figure 9–8. Valve Driver Outputs

Table 9–7. Valve Driver Outputs Assignment

Terminal Number	Signal Name
1+	Valve Drive 1+
1-	Valve Drive 1-
2+	Valve Drive 2+
2-	Valve Drive 2-
3+	Valve Drive 3+
3-	Valve Drive 3-
4+	Valve Drive 4+
4-	Valve Drive 4-
5+	Valve Drive 5+
5-	Valve Drive 5-
6+	Valve Drive 6+
6-	Valve Drive 6-
7+	Valve Drive 7+
7-	Valve Drive 7-
8+	Valve Drive 8+
8-	Valve Drive 8-

Note Intended for 24 V valves. These outputs will also drive any DC load of 22–24 VDC, up to 300 mA. ▲

Internal Zero/Span and Sample Valves

With the zero/span assembly option, a source of span gas is connected to the SPAN port and a source of zero air is connected to the ZERO IN port as shown in Figure 9–9. Zero in and span gas should be supplied at atmospheric pressure. It may be necessary to use an atmospheric dump bypass plumbing arrangement to accomplish this.

For more information, refer to the "Installation and Setup" chapter and the "Operation" chapter.

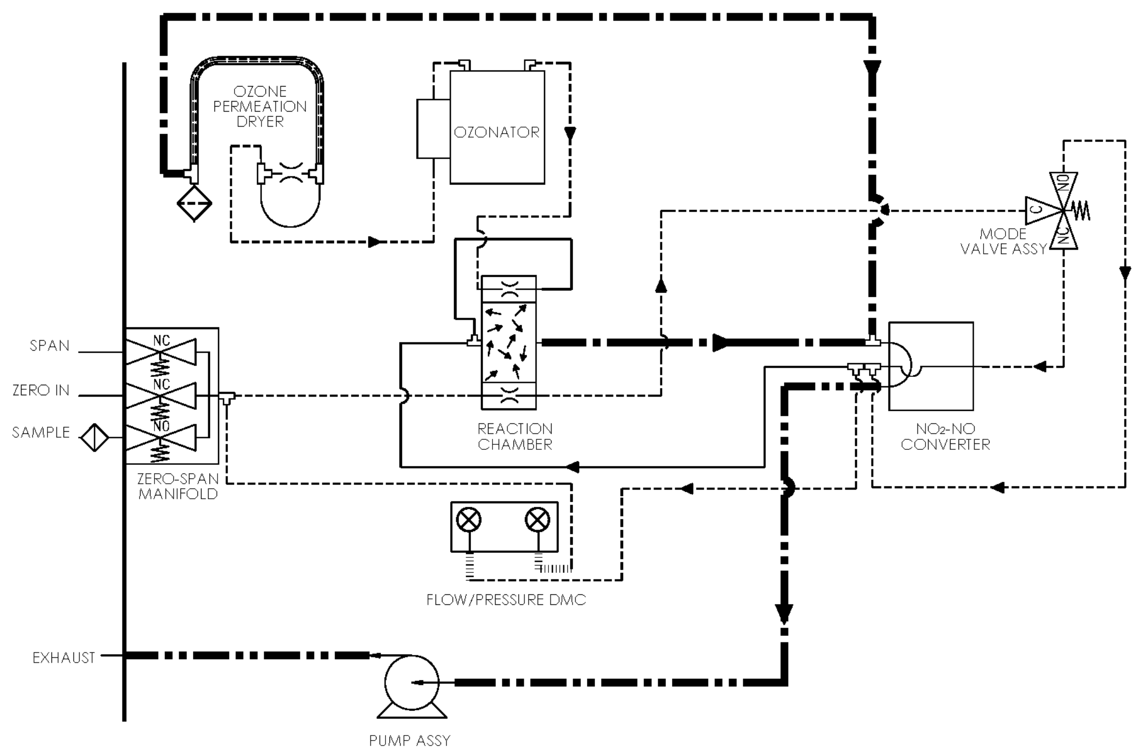


Figure 9–9. Flow Diagram, Zero/Span Option

Lag Volume

The 42iQ is available with the following Lag Volume option.

Principle of Operation

The 42iQ is based on the principle that nitric oxide (NO) and ozone react to produce a characteristic luminescence with an intensity linearly proportional to the NO concentration. Infrared light emission results when electronically excited NO_2 molecules decay to lower energy states.

Specifically,

$$NO + O_3 \rightarrow NO_2 + O_2 + h\upsilon$$

Nitrogen dioxide (NO_2) must first be transformed into NO before it can be measured using the chemiluminescent reaction. NO_2 is converted to NO by a molybdenum NO_2-to-NO converter heated to about 325 °C.

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

The ambient air sample enters the 42iQ through an inline PTFE particulate filter, through a flow control capillary, and then splits between the NO and the NO_x channel. In the NO channel, the split sample is directed to the common port of the three-way solenoid valve. The sample is then routed either to the inlet tee of the reaction chamber or joins the exhaust of the reaction chamber. In the NO_x channel, the split sample is directed to the common port of a second three-way solenoid valve after having passed through the NO_2 converter and a lag volume, as shown in Figure 9–10. The “delayed” sample is then routed identically to the NO channel.

The two channels operate 180° out of phase, that is, when the instrument is monitoring NO, the NO_x sample is being bypassed, and when the instrument is monitoring NO_x, the NO sample is being bypassed. The solenoids switch every 5 seconds and the size of the lag volume has been chosen so the same original sample is being monitored by both the NO and the NO_x channels. In this way, any positive or negative errors in the NO_2 signal (determined by the difference between the NO_x and NO readings) is minimized - especially in a situation where the sample is changing rapidly, e.g., an urban traffic environment.

The 42iQ stores the NO signal obtained during the first half of the solenoid cycle, determines the NO_x signal during the second half of the solenoid cycle, and then calculates and updates a NO, NO_2, and NO_x signal every 10 seconds. Averages are available then from 10 to 300 seconds.

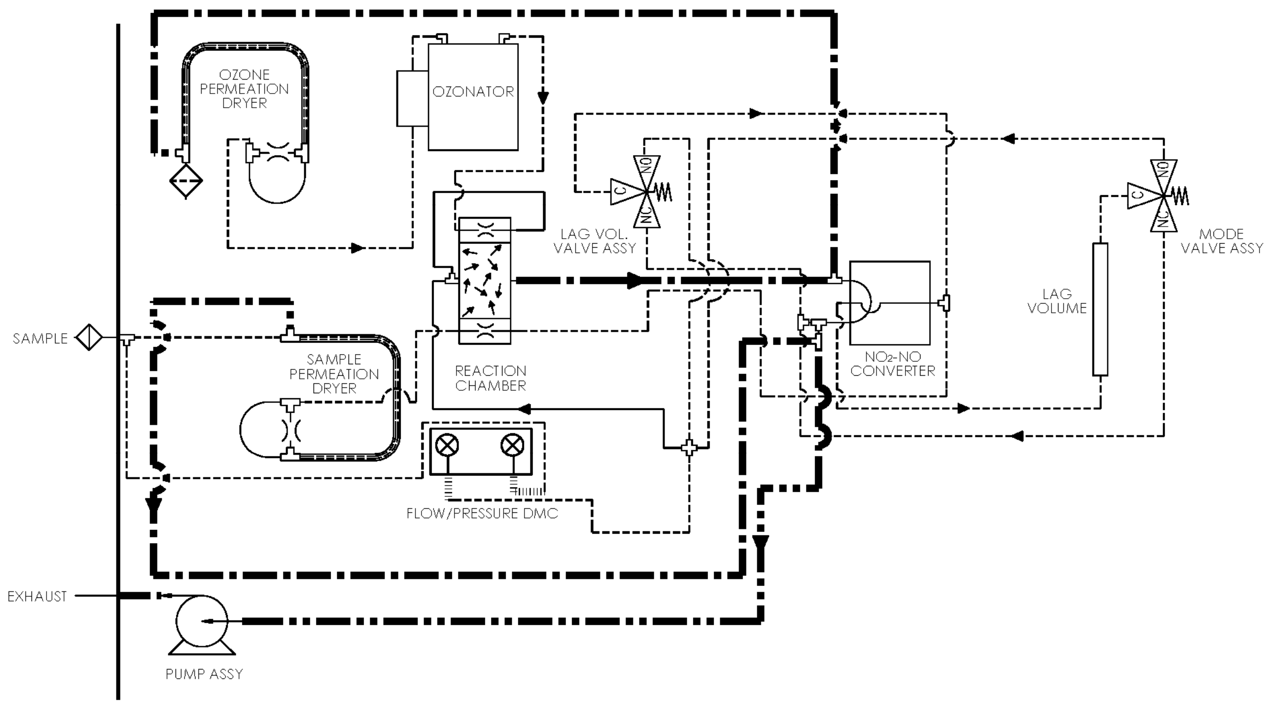


Figure 9–10. Flow Diagram, Lag Volume

Lag Volume Test

Use the following procedure to test the 42iQ with lag volume option.

1. Set the NO range to 1,000 ppb and the averaging time to 10 seconds.

2. Introduce approximately 800 ppb NO into the 42iQ. Wait for a stable reading and then record the NO_2 reading. Next, introduce zero air into the 42iQ. Wait until the instrument reads close to zero (<3 ppb). Repeat the above procedure two more times. Take the average of the three NO_2 readings. The average NO_2 reading should be less than 50 ppb.

Ammonia Scrubber

The ammonia scrubber is mounted internally and removes ammonia from the sample air.

NO_2-to-NO Converter

The 42iQ includes a Molybdenum NO_2-to-NO converter as standard equipment. A stainless steel converter is available as an option.

Sample Permeation Dryer

The sample permeation dryer option is used when there may be widely varying levels of ambient water vapor present. The dryer stabilizes the moisture content of the sample stream providing a constant dew-point at the outlet over a wide range of inlet ambient moisture levels.

A secondary benefit of the sample dryer option is its ability to remove ambient levels of ammonia (NH_3) from the sample stream.

Internal Permeation Span Source

The Internal Permeation Span Source option is designed to provide a simple span check. This option is intended as a quick, convenient check to be used between zero and span calibrations for determining instrument malfunction or drift. Because this option does not precisely control dilution gas flow, it should not be used as a basis for instrument zero and span adjustments, calibration updates or adjustment of ambient data.

Whenever there is an indication of possible instrument drift or malfunction, a full zero and calibration should be performed prior to corrective action. For further information on zero, span and calibration of air pollution monitors, refer to Section 2.0.9 of the US EPA's *Quality Assurance Handbook for Air Pollution Measurement Systems (Volume II)*.

Figure 9–11 shows how this option is integrated with the 42iQ components. During normal operation, the pump draws zero air through the permeation oven and out the instrument exhaust. When performing a single point span check, the sample valve is energized, closing the sample valve, and the Perm valve is energized, opening the perm valve. This directs the zero air/NO_2 gas mixture from the permeation oven into the sample path for measurement.

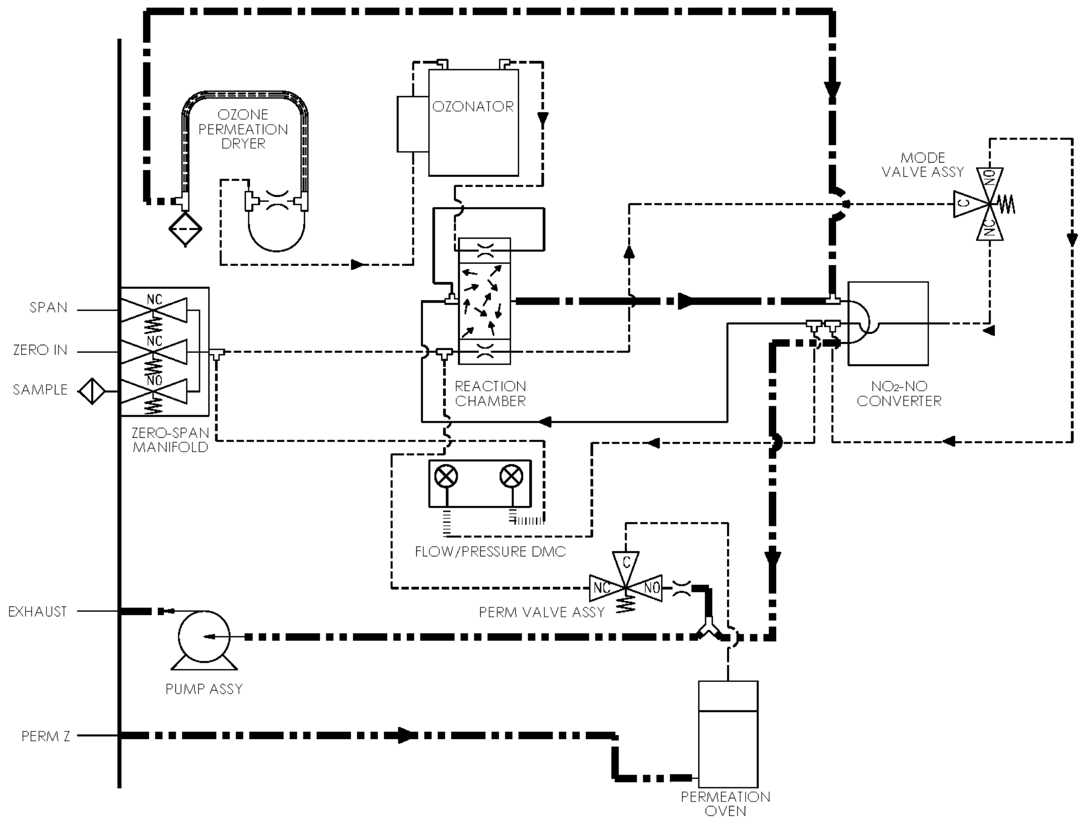


Figure 9–11. Internal Permeation Span Source Flow Diagram

Permeation Tube Installation

Use the following procedure to install the permeation tube.

CAUTION

CAUTION Allow oven to cool down prior to servicing. ▲

1. Lift oven cover up.

2. Lift and unlatch two oven cover handles.

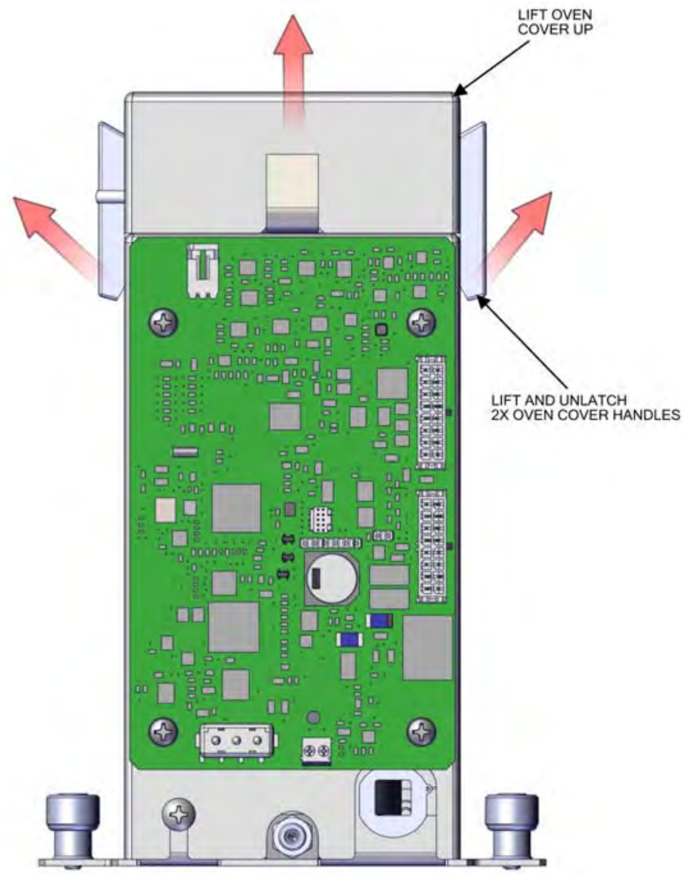


Figure 9–12. Installing Glass Tube pt 1

3. Unfasten nut. Loosen thumb screw 2X full counter clock rotation.

4. Loosening the thumb screw deflates the o-ring making it easier to pull the thermistor assembly out.

5. Pull thermistor assembly upwards.

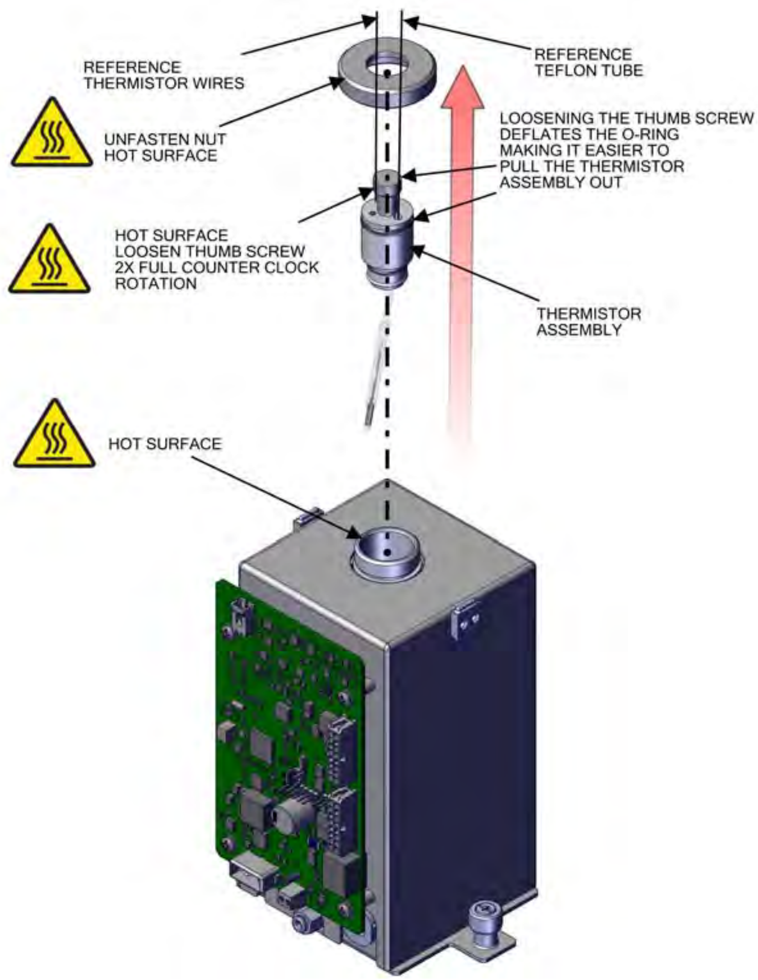


Figure 9–13. Installing Glass Tube pt 2

6. Push and gently twist tube dispersion glass upwards and seat into o-ring.

Note Make sure PTFE tube and thermistor is inside the dispersion glass. Keep glass clean by using kimwipes or similar material to handle glass. ▲

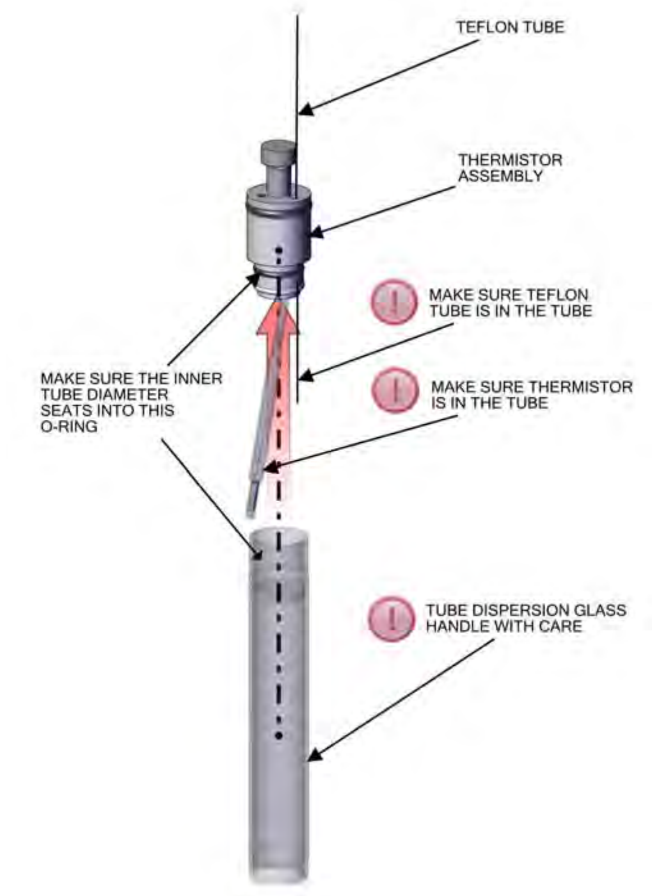


Figure 9–14. Installing Glass Tube pt 3

7. Insert thermistor assembly into oven tube. Make sure it bottoms out.

8. Tighten thumb screw to expand o-ring for complete seal.

9. Fasten nut.

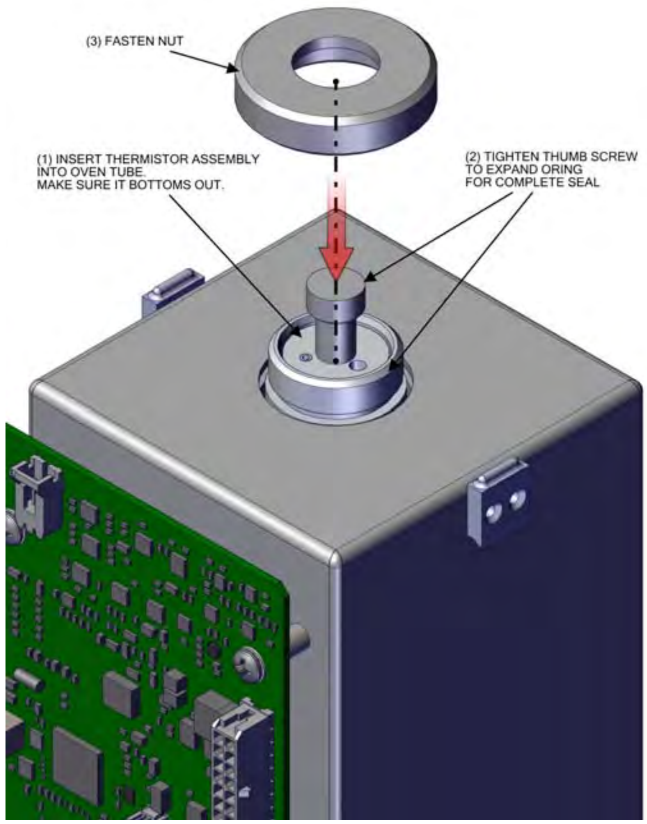


Figure 9–15. Installing Glass Tube pt 4

10. Latch oven cover handles.

Computation of Concentrations

The computation of NO_2 output level is shown in the following information. Note that is assumed that all devices are properly calibrated and that all flows are corrected to 25 °C and 1 atm.

Permeation Tube:

$$Output(ppm) = \frac{(R)(K)}{Q_o}$$

Where:

R = permeation rate in ng/min

Q_0 = flow rate of gas (scc/min) during span mode

K = constant for the specific permeant = 24.45 / MW

MW = molecular weight

PTFE Particulate Filter

A 5-10 micron pore size, two-inch diameter PTFE element is available for the 42iQ. This filter should be installed just prior to the SAMPLE bulkhead. When using a filter, all calibrations and span checks must be performed through the filter.

Ozone Particulate Filter

The ozone particulate filter minimizes the potential for contamination of the capillary and reaction chamber by trapping any particulate matter before passing through the capillary and reaction chamber.

Appendix A
Safety, Warranty, and WEEE

Safety

Review the following information carefully before using the instrument. This manual provides specific information on how to operate the instrument, however if the instrument is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Safety and Equipment Damage Alerts

This manual contains important information to alert you to potential safety hazards and risks of equipment damage. Refer to the following types of alerts you may see in this manual.

Safety and Equipment Damage Alert Descriptions

Alert	Description
DANGER	A hazard is present that will result in death or serious personal injury if the warning is ignored. ▲
WARNING	A hazard is present or an unsafe practice can result in serious personal injury if the warning is ignored. ▲
CAUTION	The hazard or unsafe practice could result in minor to moderate personal injury if the warning is ignored. ▲
Equipment Damage	The hazard or unsafe practice could result in property damage if the warning is ignored. ▲

Safety and Equipment Damage Alerts in this Manual

Alert	Description
WARNING	If the equipment is operated in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. ▲
	The service procedures in this manual are restricted to qualified service personnel only. ▲
Equipment Damage	Do not attempt to lift the analyzer by the cover or other external fittings. ▲
	This adjustment should only be performed by an instrument service technician. ▲

Warranty

Seller warrants that the Products will operate or perform substantially in conformance with Seller's published specifications and be free from defects in material and workmanship, when subjected to normal, proper and intended usage by properly trained personnel, for the period of time set forth in the product documentation, published specifications or package inserts. If a period of time is not specified in Seller's product documentation, published specifications or package inserts, the warranty period shall be one (1) year from the date of shipment to Buyer for equipment and ninety (90) days for all other products (the "Warranty Period"). Seller agrees during the Warranty Period, to repair or replace, at Seller's option, defective Products so as to cause the same to operate in substantial conformance with said published specifications; provided that (a) Buyer shall promptly notify Seller in writing upon the discovery of any defect, which notice shall include the product model and serial number (if applicable) and details of the warranty claim; (b) after Seller's review, Seller will provide Buyer with service data and/or a Return Material Authorization ("RMA"), which may include biohazard decontamination procedures and other product-specific handling instructions; and (c) then, if applicable, Buyer may return the defective Products to Seller with all costs prepaid by Buyer. Replacement parts may be new or refurbished, at the election of Seller. All replaced parts shall become the property of Seller. Shipment to Buyer of repaired or replacement Products shall be made in accordance with the Delivery provisions of the Seller's Terms and Conditions of Sale. Consumables, including but not limited to lamps, fuses, batteries, bulbs and other such expendable items, are expressly excluded from the warranty under this warranty.

Notwithstanding the foregoing, Products supplied by Seller that are obtained by Seller from an original manufacturer or third party supplier are not warranted by Seller, but Seller agrees to assign to Buyer any warranty rights in such Product that Seller may have from the original manufacturer or third party supplier, to the extent such assignment is allowed by such original manufacturer or third party supplier.

In no event shall Seller have any obligation to make repairs, replacements or corrections required, in whole or in part, as the result of (i) normal wear and tear, (ii) accident, disaster or event of force majeure, (iii) misuse, fault or negligence of or by Buyer, (iv) use of the Products in a manner for which they were not designed, (v) causes external to the Products such as, but not limited to, power failure or electrical power surges, (vi) improper storage and handling of the Products or (vii) use of the Products in combination with equipment or software not supplied by Seller. If Seller determines that Products for which Buyer has requested warranty services are not covered by the warranty hereunder, Buyer shall pay or reimburse Seller for all costs of investigating and responding to such request at Seller's then prevailing time and materials rates. If Seller provides repair services or replacement parts that are not covered by the warranty provided in this warranty, Buyer shall pay Seller therefor at Seller's then prevailing time and materials rates. ANY INSTALLATION, MAINTENANCE, REPAIR, SERVICE, RELOCATION OR ALTERATION TO OR OF, OR OTHER TAMPERING WITH, THE PRODUCTS PERFORMED BY ANY PERSON OR ENTITY OTHER THAN SELLER WITHOUT SELLER'S PRIOR WRITTEN APPROVAL, OR ANY USE OF REPLACEMENT PARTS NOT SUPPLIED BY SELLER, SHALL IMMEDIATELY VOID AND CANCEL ALL WARRANTIES WITH RESPECT TO THE AFFECTED PRODUCTS.

THE OBLIGATIONS CREATED BY THIS WARRANTY STATEMENT TO REPAIR OR REPLACE A DEFECTIVE PRODUCT SHALL BE THE SOLE REMEDY OF BUYER IN THE EVENT OF A DEFECTIVE PRODUCT. EXCEPT AS EXPRESSLY PROVIDED IN THIS WARRANTY STATEMENT, SELLER DISCLAIMS ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, ORAL OR WRITTEN, WITH RESPECT TO THE PRODUCTS, INCLUDING WITHOUT LIMITATION ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. SELLER DOES NOT WARRANT THAT THE PRODUCTS ARE ERROR-FREE OR WILL ACCOMPLISH ANY PARTICULAR RESULT.

WEEE Compliance

This product is required to comply with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC. It is marked with the following symbol:

Thermo Fisher Scientific has contracted with one or more recycling/disposal companies in each EU Member State, and this product should be disposed of or recycled through them. Further information on Thermo Fisher Scientific's compliance with these Directives, the recyclers in your country, and information on Thermo Fisher Scientific products which may assist the detection of substances subject to the RoHS Directive are available at: www.thermoscientific.com/WEEERoHS.

WEEE Symbol

The following symbol and description identify the WEEE marking used on the instrument and in the associated documentation.

Symbol	Description
	Marking of electrical and electronic equipment which applies to electrical and electronic equipment falling under the Directive 2002/96/EC (WEEE) and the equipment that has been put on the market after 13 August 2005. ▲

Appendix B
Quick Reference

List of Figures

List of Tables

Appendix C
GNU Lesser General Public License

BECAUSE THE LIBRARY IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE LIBRARY, TO THE EXTENT PERMITTED BY APPLICABLE LAW.

The Open Source code used in the development of this product will be provided for a period of 3-years from date of purchase to the original purchaser provided they supply Thermo Fisher Scientific with the applicable serial number for the product the Open Source code is being requested for.

[This is the first released version of the Lesser GPL. It also counts as the successor of the GNU Library Public License, version 2, hence the version number 2.1.]

Preamble

The licenses for most software are designed to take away your freedom to share and change it. By contrast, the GNU General Public Licenses are intended to guarantee your freedom to share and change free software--to make sure the software is free for all its users.

This license, the Lesser General Public License, applies to some specially designated software packages--typically libraries--of the Free Software Foundation and other authors who decide to use it. You can use it too, but we suggest you first think carefully about whether this license or the ordinary General Public License is the better strategy to use in any particular case, based on the explanations below.

When we speak of free software, we are referring to freedom of use, not price. Our General Public Licenses are designed to make sure that you have the freedom to distribute copies of free software (and charge for this service if you wish); that you receive source code or can get it if you want it;

that you can change the software and use pieces of it in new free programs; and that you are informed that you can do these things.

To protect your rights, we need to make restrictions that forbid distributors to deny you these rights or to ask you to surrender these rights. These restrictions translate to certain responsibilities for you if you distribute copies of the library or if you modify it.

For example, if you distribute copies of the library, whether gratis or for a fee, you must give the recipients all the rights that we gave you. You must make sure that they, too, receive or can get the source code. If you link other code with the library, you must provide complete object files to the recipients, so that they can relink them with the library after making changes to the library and recompiling it. And you must show them these terms so they know their rights.

We protect your rights with a two-step method: (1) we copyright the library, and (2) we offer you this license, which gives you legal permission to copy, distribute and/or modify the library.

To protect each distributor, we want to make it very clear that there is no warranty for the free library. Also, if the library is modified by someone else and passed on, the recipients should know that what they have is not the original version, so that the original author's reputation will not be affected by problems that might be introduced by others.

Finally, software patents pose a constant threat to the existence of any free program. We wish to make sure that a company cannot effectively restrict the users of a free program by obtaining a restrictive license from a patent holder. Therefore, we insist that any patent license obtained for a version of the library must be consistent with the full freedom of use specified in this license.

Most GNU software, including some libraries, is covered by the ordinary GNU General Public License. This license, the GNU Lesser General Public License, applies to certain designated libraries, and is quite different from the ordinary General Public License. We use this license for certain libraries in order to permit linking those libraries into non-free programs.

When a program is linked with a library, whether statically or using a shared library, the combination of the two is legally speaking a combined work, a derivative of the original library. The ordinary General Public License therefore permits such linking only if the entire combination fits its criteria of freedom. The Lesser General Public License permits more lax criteria for linking other code with the library.

We call this license the "Lesser" General Public License because it does Less to protect the user's freedom than the ordinary General Public License. It also provides other free software developers Less of an advantage over competing non-free programs. These disadvantages are the reason we use the ordinary General Public License for many libraries. However, the Lesser license provides advantages in certain special circumstances.

For example, on rare occasions, there may be a special need to encourage the widest possible use of a certain library, so that it becomes a de-facto standard. To achieve this, non-free programs must be allowed to use the library. A more frequent case is that a free library does the same job as widely used non-free libraries. In this case, there is little to gain by limiting the free library to free software only, so we use the Lesser General Public License.

In other cases, permission to use a particular library in non-free programs enables a greater number of people to use a large body of free software. For example, permission to use the GNU C Library in non-free programs enables many more people to use the whole GNU operating system, as well as its variant, the GNU/Linux operating system.

Although the Lesser General Public License is Less protective of the users' freedom, it does ensure that the user of a program that is linked with the Library has the freedom and the wherewithal to run that program using a modified version of the Library.

The precise terms and conditions for copying, distribution and modification follow. Pay close attention to the difference between a "work based on the library" and a "work that uses the library". The former contains code derived from the library, whereas the latter must be combined with the library in order to run.

GNU LESSER GENERAL PUBLIC LICENSE TERMS AND CONDITIONS FOR COPYING, DISTRIBUTION AND MODIFICATION

0. This License Agreement applies to any software library or other program which contains a notice placed by the copyright holder or other authorized party saying it may be distributed under the terms of this Lesser General Public License (also called "this License"). Each licensee is addressed as "you".

A "library" means a collection of software functions and/or data prepared so as to be conveniently linked with application programs (which use some of those functions and data) to form executables.

The "Library", below, refers to any such software library or work which has been distributed under these terms. A "work based on the Library" means either the Library or any derivative work under copyright law: that is to say, a work containing the Library or a portion of it, either verbatim or with modifications and/or translated straightforwardly into another language. (Hereinafter, translation is included without limitation in the term "modification".)

"Source code" for a work means the preferred form of the work for making modifications to it. For a library, complete source code means all the source code for all modules it contains, plus any associated interface definition files, plus the scripts used to control compilation and installation of the library.

Activities other than copying, distribution and modification are not covered by this License; they are outside its scope. The act of running a program using the Library is not restricted, and output from such a program is covered only if its contents constitute a work based on the Library (independent of the use of the Library in a tool for writing it). Whether that is true depends on what the Library does and what the program that uses the Library does.

1. You may copy and distribute verbatim copies of the Library's complete source code as you receive it, in any medium, provided that you conspicuously and appropriately publish on each copy an appropriate copyright notice and disclaimer of warranty; keep intact all the notices that refer to this License and to the absence of any warranty; and distribute a copy of this License along with the Library.

You may charge a fee for the physical act of transferring a copy, and you may at your option offer warranty protection in exchange for a fee.

2. You may modify your copy or copies of the Library or any portion of it, thus forming a work based on the Library, and copy and distribute such modifications or work under the terms of Section 1 above, provided that you also meet all of these conditions:

a) The modified work must itself be a software library.

b) You must cause the files modified to carry prominent notices stating that you changed the files and the date of any change.

c) You must cause the whole of the work to be licensed at no charge to all third parties under the terms of this License.

d) If a facility in the modified Library refers to a function or a table of data to be supplied by an application program that uses the facility, other than as an argument passed when the facility is invoked, then you must make a good faith effort to ensure that, in the event an application does not supply such function or table, the facility still operates, and performs whatever part of its purpose remains meaningful.

(For example, a function in a library to compute square roots has a purpose that is entirely well-defined independent of the application. Therefore, Subsection 2d requires that any application-supplied function or table used by this function must be optional: if the application does not supply it, the square root function must still compute square roots.)

These requirements apply to the modified work as a whole. If identifiable sections of that work are not derived from the Library, and can be reasonably considered independent and separate works in themselves, then this License, and its terms, do not apply to those sections when you distribute them as separate works. But when you distribute the same sections as part of a whole which is a work based on the Library, the distribution of the whole must be on the terms of this License, whose permissions for other licensees extend to the entire whole, and thus to each and every part regardless of who wrote it.

Thus, it is not the intent of this section to claim rights or contest your rights to work written entirely by you; rather, the intent is to exercise the right to control the distribution of derivative or collective works based on the Library.

In addition, mere aggregation of another work not based on the Library with the Library (or with a work based on the Library) on a volume of a storage or distribution medium does not bring the other work under the scope of this License.

3. You may opt to apply the terms of the ordinary GNU General Public License instead of this License to a given copy of the Library. To do this, you must alter all the notices that refer to this License, so that they refer to the ordinary GNU General Public License, version 2, instead of to this License. (If a newer version than version 2 of the ordinary GNU General Public License has appeared, then you can specify that version instead if you wish.) Do not make any other change in these notices.

Once this change is made in a given copy, it is irreversible for that copy, so the ordinary GNU General Public License applies to all subsequent copies and derivative works made from that copy. This option is useful when you wish to copy part of the code of the Library into a program that is not a library.

4. You may copy and distribute the Library (or a portion or derivative of it, under Section 2) in object code or executable form under the terms of Sections 1 and 2 above provided that you accompany it with the complete corresponding machine-readable source code, which must be distributed under the terms of Sections 1 and 2 above on a medium customarily used for software interchange.

If distribution of object code is made by offering access to copy from a designated place, then offering equivalent access to copy the source code from the same place satisfies the requirement to distribute the source code, even though third parties are not compelled to copy the source along with the object code.

5. A program that contains no derivative of any portion of the Library, but is designed to work with the Library by being compiled or linked with it, is

called a "work that uses the Library". Such a work, in isolation, is not a derivative work of the Library, and therefore falls outside the scope of this License.

However, linking a "work that uses the Library" with the Library creates an executable that is a derivative of the Library (because it contains portions of the Library), rather than a "work that uses the library". The executable is therefore covered by this License. Section 6 states terms for distribution of such executables.

When a "work that uses the Library" uses material from a header file that is part of the Library, the object code for the work may be a derivative work of the Library even though the source code is not. Whether this is true is especially significant if the work can be linked without the Library, or if the work is itself a library. The threshold for this to be true is not precisely defined by law.

If such an object file uses only numerical parameters, data structure layouts and accessors, and small macros and small inline functions (ten lines or less in length), then the use of the object file is unrestricted, regardless of whether it is legally a derivative work. (Executables containing this object code plus portions of the Library will still fall under Section 6.)

Otherwise, if the work is a derivative of the Library, you may distribute the object code for the work under the terms of Section 6. Any executables containing that work also fall under Section 6, whether or not they are linked directly with the Library itself.

6. As an exception to the Sections above, you may also combine or link a "work that uses the Library" with the Library to produce a work containing portions of the Library, and distribute that work under terms of your choice, provided that the terms permit modification of the work for the customer's own use and reverse engineering for debugging such modifications.

You must give prominent notice with each copy of the work that the Library is used in it and that the Library and its use are covered by this License. You must supply a copy of this License. If the work during execution displays copyright notices, you must include the copyright notice for the Library among them, as well as a reference directing the user to the copy of this License. Also, you must do one of these things:

a) Accompany the work with the complete corresponding machine-readable source code for the Library including whatever changes were used in the work (which must be distributed under Sections 1 and 2 above); and, if the work is an executable linked with the Library, with the complete machine-readable "work that uses the Library", as object code and/or source code, so that the user can modify the Library and then relink to produce a modified executable containing the modified Library. (It is understood that the user who changes the contents of definitions files in the Library will not necessarily be able to recompile the application to use the modified definitions.)

b) Use a suitable shared library mechanism for linking with the Library. A suitable mechanism is one that (1) uses at run time a copy of the library already present on the user's computer system, rather than copying library functions into the executable, and (2) will operate properly with a modified version of the library, if the user installs one, as long as the modified version is interface-compatible with the version that the work was made with.

c) Accompany the work with a written offer, valid for at least three years, to give the same user the materials specified in Subsection 6a, above, for a charge no more than the cost of performing this distribution.

d) If distribution of the work is made by offering access to copy from a designated place, offer equivalent access to copy the above specified materials from the same place.

e) Verify that the user has already received a copy of these materials or that you have already sent this user a copy.

For an executable, the required form of the "work that uses the Library" must include any data and utility programs needed for reproducing the executable from it. However, as a special exception, the materials to be distributed need not include anything that is normally distributed (in either source or binary form) with the major components (compiler, kernel, and so on) of the operating system on which the executable runs, unless that component itself accompanies the executable.

It may happen that this requirement contradicts the license restrictions of other proprietary libraries that do not normally accompany the operating system. Such a contradiction means you cannot use both them and the Library together in an executable that you distribute.

7. You may place library facilities that are a work based on the Library side-by-side in a single library together with other library facilities not covered by this License, and distribute such a combined library, provided that the separate distribution of the work based on the Library and of the other library facilities is otherwise permitted, and provided that you do these two things:

a) Accompany the combined library with a copy of the same work based on the Library, uncombined with any other library facilities. This must be distributed under the terms of the Sections above.

b) Give prominent notice with the combined library of the fact that part of it is a work based on the Library, and explaining where to find the accompanying uncombined form of the same work.

8. You may not copy, modify, sublicense, link with, or distribute the Library except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense, link with, or distribute the Library is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

9. You are not required to accept this License, since you have not signed it. However, nothing else grants you permission to modify or distribute the Library or its derivative works. These actions are prohibited by law if you do not accept this License. Therefore, by modifying or distributing the Library (or any work based on the Library), you indicate your acceptance of this License to do so, and all its terms and conditions for copying, distributing or modifying the Library or works based on it.

10. Each time you redistribute the Library (or any work based on the Library), the recipient automatically receives a license from the original licensor to copy, distribute, link with or modify the Library subject to these terms and conditions. You may not impose any further restrictions on the recipients' exercise of the rights granted herein. You are not responsible for enforcing compliance by third parties with this License.

11. If, as a consequence of a court judgment or allegation of patent infringement or for any other reason (not limited to patent issues), conditions are imposed on you (whether by court order, agreement or otherwise) that contradict the conditions of this License, they do not excuse you from the conditions of this License. If you cannot distribute so as to satisfy simultaneously your obligations under this License and any other pertinent obligations, then as a consequence you may not distribute the Library at all. For example, if a patent license would not permit royalty-free redistribution of the Library by all those who receive copies directly or indirectly through you, then the only way you could satisfy both it and this License would be to refrain entirely from distribution of the Library.

If any portion of this section is held invalid or unenforceable under any particular circumstance, the balance of the section is intended to apply, and the section as a whole is intended to apply in other circumstances.

It is not the purpose of this section to induce you to infringe any patents or other property right claims or to contest validity of any such claims; this section has the sole purpose of protecting the integrity of the free software distribution system which is implemented by public license practices. Many people have made generous contributions to the wide range of software distributed through that system in reliance on consistent application of that system; it is up to the author/donor to decide if he or she is willing to distribute software through any other system and a licensee cannot impose that choice.

This section is intended to make thoroughly clear what is believed to be a consequence of the rest of this License.

12. If the distribution and/or use of the Library is restricted in certain countries either by patents or by copyrighted interfaces, the original copyright holder who places the Library under this License may add an explicit geographical distribution limitation excluding those countries, so that distribution is permitted only in or among countries not thus excluded. In such case, this License incorporates the limitation as if written in the body of this License.

13. The Free Software Foundation may publish revised and/or new versions of the Lesser General Public License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns.

Each version is given a distinguishing version number. If the Library specifies a version number of this License which applies to it and "any later version", you have the option of following the terms and conditions either of that version or of any later version published by the Free Software Foundation. If the Library does not specify a license version number, you may choose any version ever published by the Free Software Foundation.

14. If you wish to incorporate parts of the Library into other free programs whose distribution conditions are incompatible with these, write to the author to ask for permission. For software which is copyrighted by the Free Software Foundation, write to the Free Software Foundation; we sometimes make exceptions for this. Our decision will be guided by the two goals of preserving the free status of all derivatives of our free software and of promoting the sharing and reuse of software generally.

NO WARRANTY

15. BECAUSE THE LIBRARY IS LICENSED FREE OF CHARGE, THERE IS NO WARRANTY FOR THE LIBRARY, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE LIBRARY "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THE ENTIRE RISK AS TO THE QUALITY AND PERFORMANCE OF THE LIBRARY IS WITH YOU. SHOULD THE LIBRARY PROVE DEFECTIVE, YOU ASSUME THE COST OF ALL NECESSARY SERVICING, REPAIR OR CORRECTION.

16. IN NO EVENT UNLESS REQUIRED BY APPLICABLE LAW OR AGREED TO IN WRITING WILL ANY COPYRIGHT HOLDER, OR

ANY OTHER PARTY WHO MAY MODIFY AND/OR REDISTRIBUTE THE LIBRARY AS PERMITTED ABOVE, BE LIABLE TO YOU FOR DAMAGES, INCLUDING ANY GENERAL, SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING OUT OF THE USE OR INABILITY TO USE THE LIBRARY (INCLUDING BUT NOT LIMITED TO LOSS OF DATA OR DATA BEING RENDERED INACCURATE OR LOSSES SUSTAINED BY YOU OR THIRD PARTIES OR A FAILURE OF THE LIBRARY TO OPERATE WITH ANY OTHER SOFTWARE), EVEN IF SUCH HOLDER OR OTHER PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

END OF TERMS AND CONDITIONS

How to Apply These Terms to Your New Libraries

If you develop a new library, and you want it to be of the greatest possible use to the public, we recommend making it free software that everyone can redistribute and change. You can do so by permitting redistribution under these terms (or, alternatively, under the terms of the ordinary General Public License).

To apply these terms, attach the following notices to the library. It is safest to attach them to the start of each source file to most effectively convey the exclusion of warranty; and each file should have at least the "copyright" line and a pointer to where the full notice is found.

<one line to give the library's name and a brief idea of what it does.>
Copyright (C) <year> <name of author>

This library is free software; you can redistribute it and/or modify it under the terms of the GNU Lesser General Public License as published by the Free Software Foundation; either version 2.1 of the License, or (at your option) any later version.

This library is distributed in the hope that it will be useful, but WITHOUT ANY WARRANTY; without even the implied warranty of MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE. See the GNU Lesser General Public License for more details.

You should have received a copy of the GNU Lesser General Public License along with this library; if not, write to the Free Software Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301 USA

Also add information on how to contact you by electronic and paper mail.

You should also get your employer (if you work as a programmer) or your school, if any, to sign a "copyright disclaimer" for the library, if necessary. Here is a sample; alter the names:

Yoyodyne, Inc., hereby disclaims all copyright interest in the library `Frob' (a library for tweaking knobs) written by James Random Hacker.

<signature of Ty Coon>, 1 April 1990

Ty Coon, President of Vice

That's all there is to it!

Nokia Qt LGPL Exception version 1.1

As an additional permission to the GNU Lesser General Public License version 2.1, the object code form of a ""work that uses the Library"" may incorporate material from a header file that is part of the Library. You may distribute such object code under terms of your choice, provided that:

(i) the header files of the Library have not been modified; and

(ii) the incorporated material is limited to numerical parameters, data structure layouts, accessors, macros, inline functions and templates; and

(iii) you comply with the terms of Section 6 of the GNU Lesser General Public License version 2.1.

Moreover, you may apply this exception to a modified version of the Library, provided that such modification does not involve copying material from the Library into the modified Library's header files unless such material is limited to (i) numerical parameters; (ii) data structure layouts; (iii) accessors; and (iv) small macros, templates and inline functions of five lines or less in length.

Furthermore, you are not required to apply this additional permission to a modified version of the Library.

USA
27 Forge Parkway
Franklin, MA 02038
Ph: (508) 520-0430
Fax: (508) 520-2800
orders.aqi@thermofisher.com

India
C/327, TTC Industrial Area
MIDC Pawane
New Mumbai 400 705, India
Ph: +91 22 4157 8800
india@thermofisher.com

China
+Units 702-715, 7th Floor
Tower West, Yonghe
Beijing, China 100007
Ph: +86 10 84193588
info.eid.china@thermofisher.com

Europe
Ion Path, Road Three,
Winsford, Cheshire CW73GA UK
Ph: +44 1606 548700
Fax: +44 1606 548711
sales.epm.uk@thermofisher.com

Find out more at thermofisher.com/42iQ

ThermoFisher
SCIENTIFIC