AERODYNE RESEARCH, Inc.

CAPS NO_2 Monitor

(SILVER)

(Fast Response Version)

SEPTEMBER, 2019

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OVERVIEW

MEASUREMENT SPECIFICATIONS

Measurement Range:	0-2000 ppb
Resolution:	0.01 ppb
Precision (2σ, 1 s):	< 0.5 ppb (at [NO_2] < 50 ppb)
Time Response:	1-2 secondS
Baseline Drift:	± 3 ppb/24 hrs
Span Drift:	negligible

PHYSICAL SPECIFICATIONS

Sample Flow Rate:	1.3 liters per minute
Cell Pressure:	ambient
Cell Temperature:	~5 ℃ above ambient
Power Usage:	< 40 Watts
Weight:	13 kg (not including mounting brackets
Size:	~65 cm x 43 cm x 23 cm (L x W x H) mounting brackets provided [19” rack mount, 5U, 24” deep]

INSTRUMENT CONTROL

1. No external controls on monitor
2. All instrument operating parameters adjustable using software interface using RS-232, USB or ethernet connection

DATA OUTPUT

Display	Front Panel, 2 second time constant (± 1 digit)
RS-232	Rear Panel, 1 sample per second or slower (no handshake allowed) DB-9 connector – **null modem cable required**
USB	Rear Panel (Male A to Male B cable provided)
Ethernet	
On-Board	25 GBytes of stored data

SAMPLE HANDLING (on back panel)

Inlet	Stainless Steel, ¼” Swagelok™ connection on back panel
Filter	Internal Filter Cartridge (with replaceable filter element)- removes all particles with diameter > 10 nm minimal pressure drop – compatible with nitrogen dioxide
Exhaust	Brass ¼” Swagelock™ connection on back panel

Use stainless steel or PFA (perfluoroalkoxy – a form of Teflon) tubing and fittings. Use of other metals and especially organic-based materials (Tygon, rubber, PVC, etc.) will result in highly inaccurate readings.

NOTES:

1. The monitor will accept a vacuum up to ~300 Torr below ambient. However, mirror contamination can occur when the vacuum is released because of particle upset. If a substantial vacuum is encountered, attempt to release that vacuum very slowly.

2. For samples with high particle loadings (such as diesel engine exhaust), the user should provide an external particle filter that removes particles with diameters greater than 1 micron. This filter should be compatible with the high flow rate and the presence of NO_2. A 50 or 75 mm diameter Teflon filter with a pore size of 1-2 microns is one example of a suitable filter.

3. If using the monitor in situations where NO_2 concentrations are above 0.5 ppm (**NO_2 is a toxic gas**) , the exhaust gas from the monitor should be vented properly. In order to do so, a tube with diameter greater than 1/4" should be connected to the pump exhaust and routed to a ventilation hood or some other outlet. A popout in the rear panel can be removed in order to allow easy access to the pump exhaust.

4. For accurate results, wait at least 10 minutes after start-up for monitor to reach final operating temperature.

1. OPERATING PRINCIPLES

The Cavity Attenuated Phase Shift nitrogen dioxide (**CAPS NO_2**) monitor as deployed here operates as an optical absorption spectrometer, utilizing a blue light-emitting diode (LED) as a light source, a sample cell incorporating two high reflectivity mirrors centered at 450 nm and a vacuum photodiode detector. Its efficacy is based on the fact that nitrogen dioxide (NO_2) is a broadband absorber of light in the visible region of the spectrum. Figure 1, shown below, displays the absorption spectrum of NO_2 between 400 and 500 nm (blue to green); the specific band employed by the monitor is shown in blue.

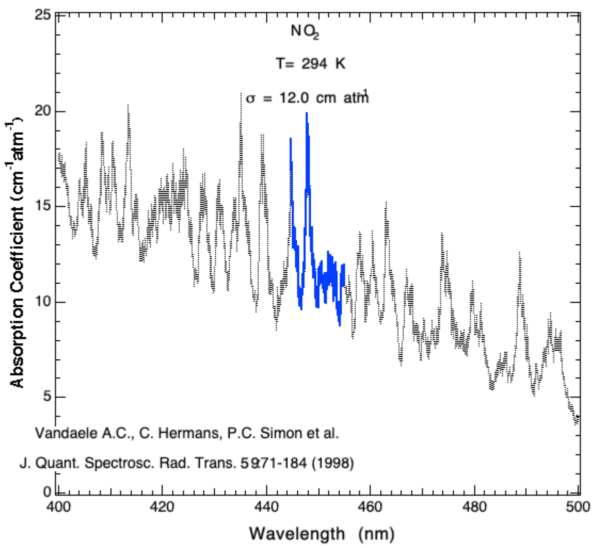


Fig.1. Absorption spectrum of nitrogen dioxide in the blue-green region. The pass-band of the absorption spectrometer is outlined in blue. The average absorption coefficient in this band is 12.0 cm atm-1.

Unlike a conventional absorption spectrometer, in which the concentration of the absorbing species is determined by measuring the attenuation of light, the CAPS monitor relies on measuring the average time spent by the light within the sample cell. The presence of nitrogen dioxide causes this average time to decrease as the NO_2 concentration increases because of the absorption. Of course, given the high velocity of light (0.3 m per nanosecond) and the weak absorption coefficient of NO_2, a very long path length within the sample cell is required in order to accurately measure this change in time. This is accomplished by forming the ends of the sample cell with high reflectivity mirrors ($R \geq 0.9998$), a configuration which provides an optical path length on the order of several kilometers. In the absence of an absorbing species, the photon lifetime within the cell is on the order of several microseconds, a magnitude which is readily measured with high accuracy.

In CAPS-based instruments, in order to measure the average time spent by the light within the sample cell, the LED output is square wave modulated and directed into the back of the first reflective mirror. The light beam passes through the absorption cell, out of the back mirror and into a detector where it appears as a distorted waveform which is characterized by a phase shift with respect to the initial modulation. (See Figure 2.) This distortion is the result of an exponential decay of the light within the cell as it leaks out through the mirrors. The amount of that phase shift (ϑ) is a function of fixed instrument properties - cell length, mirror reflectivity, and modulation frequency – and of the presence of variable concentrations of nitrogen dioxide using the following relationship:

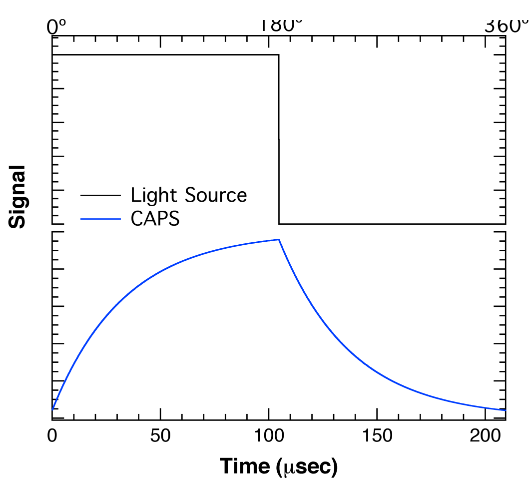


Figure 2. Waveforms of LED (top) and signal at detector (bottom)

$$\cot\vartheta = \cot\vartheta_0 + \frac{c}{2\pi f}\alpha_{NO_2}(T,P)\chi$$

where cot is the cotangent, c is the speed of light, f is the LED modulation frequency, T and P are the sample temperature and pressure respectively, α_{NO_2} is the absorption coefficient of nitrogen dioxide and χ is the mixing ratio of nitrogen dioxide. The term $\cot\vartheta_0$ is obtained from a periodic baseline measurement (using NO_2-free air). Thus,

$$\chi = [\cot\vartheta - \cot\vartheta_0]\left[\frac{2\pi f}{c\alpha_{NO_2}(T,P)}\right].$$

Note that this measurement is, in theory, an absolute measurement requiring no calibration – all the other quantities in the above expression are known. In fact, given that the light source is not monochromatic, a calibration must be taken. However, unless there is a substantial shift in the spectral output of the LED or change in filter performance, span drift should be negligible.

The configuration of the monitor is quite simple and is shown below in schematic form in Figure 3. The air sample enters the monitor and passes through a disposable filter cartridge which removes all particulates in order to prevent contamination of the mirror. The sample then proceeds through PFA tubing into a stainless steel sample cell at one end and out the other through tubing where it is directed to a 5 l min^{-1} diaphragm pump.

The high reflectivity mirrors are directly attached to the ends of the sample cell, forming the optical cavity which provides for the concentration measurement, The LED, filter and appropriate focusing optics are attached directly to the sample cell. The light emanating from the cell is directed into a vacuum photodiode where the resultant signal is integrated, digitized and sent to a PC-104 format computer where all subsequent data processing takes place. The sample cell contains both pressure and temperature sensors which allow for both accurate correction of the nitrogen dioxide absorption coefficient and baseline subtraction As noted later, the pressure reading is also used to check on the proper operation of the particle filter.

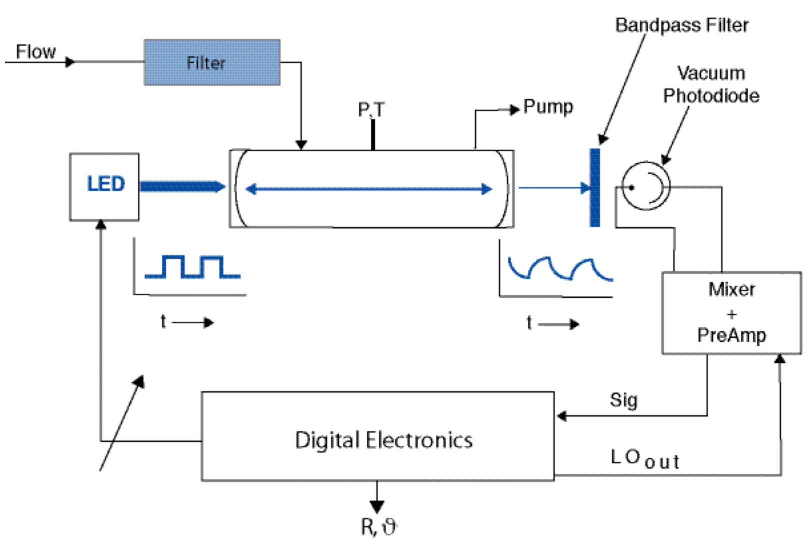


Fig. 3 Schematic of CAPS NO2 monitor.

2. GETTING STARTED

1. Unpack shipping crate which contains the monitor, power cord, USB and null modem data cables, and laptop computer.

2. **REMOVE SWAGELOCK PLUGS ON INLET AND OUTLET PORTS ON BACK PANEL BEFORE POWERING UP.**

3. Insert power cord into monitor AC/DC converter on back panel, plug into wall socket (100-240 VAC) and turn on power switch on back panel. AC/DC converter is a medical grade II power supply. All voltages within the monitor enclosure are 24 VDC or less. **The monitor takes ~30 s to boot up.**

4. The supplied laptop is already configured to operate the data acquisition software. The software will automatically log the data and store it in a folder on the desktop. It also provides all commands necessary to set up the monitor. Connect the supplied USB cable to the monitor using the USB port on back panel and to the laptop computer. Start up the software and skip to instruction 5. You can also use a null modem cable to record data using a serial port if preferred. Instructions on using the ethernet connection are provided below. You can also download a version of the data acquisition software and install it on your own Windows computer.

5. Within 30 seconds, data from the instrument should start appearing on the display panel. If no data appears:

   a. Is the USB cable if used properly installed? If using the RS-232 port, is it a null modem cable?
   b. Is the port properly designated? (Most computers have multiple series and USB ports.)

   If a connection is still not made, reboot host computer and wait for serial port designation to appear in appropriate window of Windows software. Use this designation in assigning the com port in CAPS software. If still not successful, try another serial/USB port and repeat process.

   If the monitor does not boot up, disconnect USB cable and restart monitor. Then plug USB cable back into its port.

6. The monitor is now ready for its initial setup. The default mode of the monitor is as follows:

Sample Period:	1 second
On-Board Time Stamp	Igor
Data Delimiter	comma

The sample period can be set to a number of integer values. It is recommended that sample periods longer than 30 seconds not be used for accurate results. If desired, data can be averaged post-measurement.

There are two different time stamps that can be supplied. The data acquisition software automatically provided a time stamp that mirrors that of the host computer. The monitor can also provide its own internal time stamp that appears in the data file stored on the host data acquisition computer and also in the data file that is automatically stored on board the monitor. The choice of format for the time-stamp provided on-board is left to the user.

A number of choices for the data delimiter are provided including comma (default), space, and tab.

7. Reset the baseline using a manual command if desired while flowing NO_2-free air.

8. Calibrate using instructions below. We recommend passivating the monitor with a flow of NO_2/air mixture for a period of time before attempting initial calibration.

Use of the Ethernet Port

SHIPPING MONITORS

When units are shipped into the field, run dry air through the monitor for several hours and then plug inlet and outlet ports with Swagelock plugs. This helps to prevent mirror contamination during shipping.

3. **BASELINE PROCEDURE**

Units with Scrubbers

CAPS NO_2 monitors that have been outfitted with an internal scrubber are set to take automated baselines at intervals designated by the user using the supplied DAQ software. The scrubber unit is filled with Purafil which comprises aluminum oxide pellets that have been coated with potassium permanganate which is the active scrubbing ingredient. This material will remove any acid gas entering the sample line. The scrubber units should last for at least a year of typical use. However, it is desirable to periodically test the monitor using NO_2-free air to see if the scrubber is working properly. These units will assume automated baseline mode upon startup and no further action is required.

The automated baseline feature can be disabled using the DAQ program.

User Supplied NO_2-Free Air

The CAPS NO_2 monitor has a live zero – i.e., even at a NO_2 concentration of zero, the instrument is still reading an optical loss associated with light transmission by the mirrors and Rayleigh scattering of light by air. Thus, a baseline must be periodically re-established. This is accomplished by using an adequate flow (> 2 liters per minute) of NO_2-free (clean) air attached to the monitor using a tee configuration (shown in Figure 4) which allows the excess air to vent to the environment. The user should check that there is indeed a slight excess flow of air. Inordinately high flows of gas should also be avoided to prevent over-pressurization of the system at high flow rates and small diameter tubing.

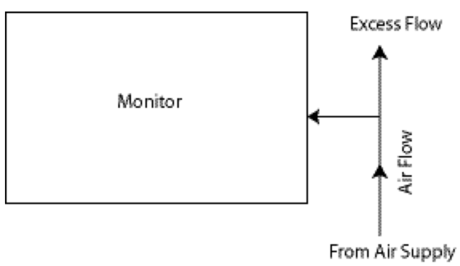


Fig. 4 . Tee arrangement used for both baseline determination and calibration.

The length of the baseline measurement can be chosen by the user depending on the precision desired. In addition the monitor must be flushed for a period of time, both before and after the actual baseline measurement. The default settings for this operation are set at 10 s flush period and 40 s baseline measurement period (60 s total). These values can be changed by the user using the **Sample Parameters** command, also under the BASELINE window. The minimum flush period that can be set is 5 seconds.

The user has three choices of how to activate a baseline:

<u>Manual Baseline</u>

Users can activate a baseline measurement at any time using the **Take Baseline** command under the BASELINE window. The measurement will commence at the beginning of the next sample period.

<u>Monitor Initiated Automated Baseline</u>

NOTE: This feature must be enabled each time upon instrument power up. (Consult Aerodyne if you wish to automatically activate this feature upon startup.)

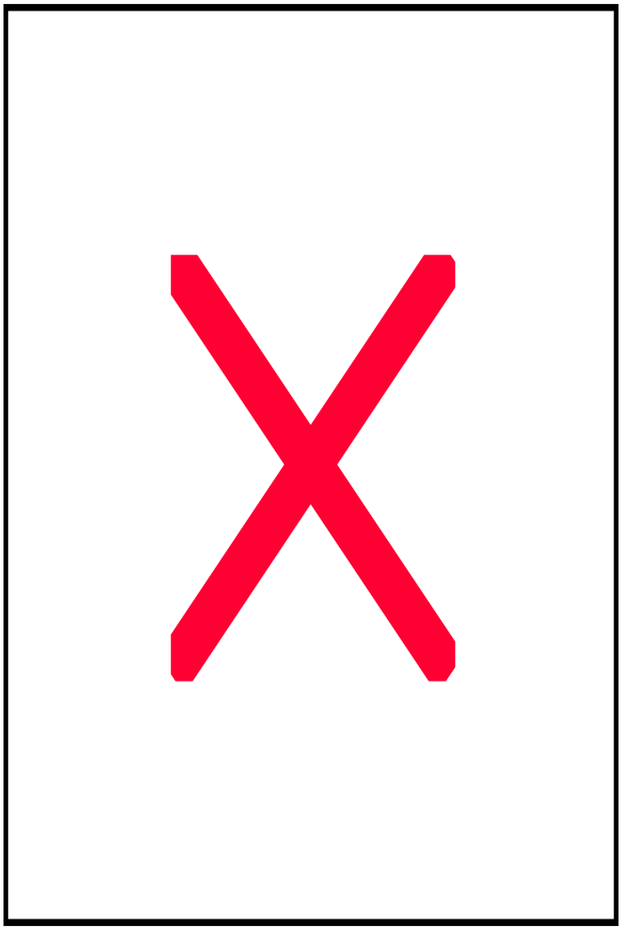
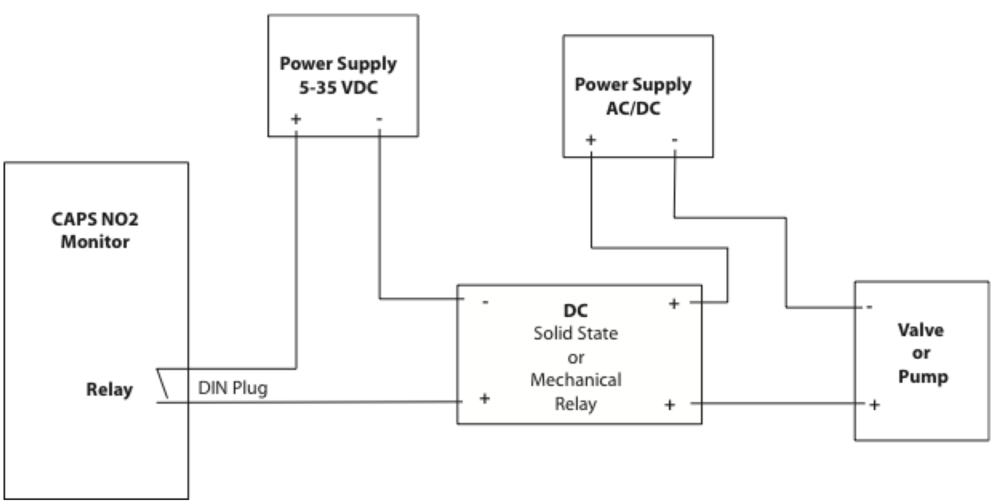


Fig.5 Schematic of required gas plumbing for automated baseline operation. See text for explanation of the two schemes.

If the **Enable Autobaseline** command is activated, the monitor will automatically perform a baseline operation according to the schedule set using the **Configure Baseline** command. Two possible arrangements for using this operation are shown in Figure 5. Scheme 1 (upper panel) involves using only 1 solenoid valve. A regulating valve (or some other critical orifice) is used to control the flow rate of the NO_2-free air. When the solenoid valve is opened, the line to the CAPS monitor is flooded with zero air; the sample inlet line acts as the vent line. If venting to the sample inlet line is not desirable (such as when other instruments are connected to the sample inlet line), the scheme in the lower panel (scheme 2) can be employed. In this case, a 3-way valve (constructed of either stainless steel or Teflon) is employed so that when the zero air is being used to provide a baseline measurement, the sample inlet line is unaffected. However, this scheme requires the use of a second valve which is closed during normal measurement. When a baseline is being established, it is opened so as to provide a vent for the zero air. This second valve should only be closed when the 3-way valve is in the position of providing sample gas. Thus, any automated operation requires appropriate delays in opening and closing that valve.

The CAPS monitor provides a switch closure through the 3 pin outlet on the rear panel labeled "**Baseline Synch Out**" that can be used to activate a solenoid valve for instance.. The connection is made by attaching wires to the outside pins (the middle pin is not connected). Under normal operating conditions, there is no connection through the plug; however, upon activation of the baseline routine, the relay closes and a connection is made. The relay re-opens upon the end of the baseline measurement period and before the second flush period. The recommended procedure for using this feature is shown below.



WARNING: The allowable current through the relay is only 1.8A at 24V. Do not attempt to operate a pump or device with a higher current load directly through the relay.

External Activation of Baseline

Users who wish to synchronize the CAPS monitor baselines with external devices can initiate a baseline at any time using the "**Baseline Trigger"** port on the rear panel. Initiation of a baseline requires a 5-24 VDC signal lasting at least 1 second at that port. The polarity of that connection is important – the pin on the right side of the connector is the positive (+) port. A baseline measurement will commence at the end of the most recent sample period. The length of the baseline measurement will be determined by the internal settings that were entered using the DAQ software.

4. CALIBRATION PROCEDURE

Although the instrument is calibrated before leaving Aerodyne, it should be recalibrated upon receipt and periodically during use to ensure the highest degree of accuracy. For the initial calibration, several tens of ppb of NO_2 should be flowed through the monitor for 30 minutes to repassivate the surfaces of the monitor. The instrument should be calibrated using at least four different levels of nitrogen dioxide (plus zero), preferably one of them equal to the highest levels expected during typical operation to ensure that linear response is provided over the desired measurement range.

The recommended procedure involves admixing the output of NO_2/air mixture of known concentration (dependent on the desired range of operation, but > 1 ppm because of gas mixture stability issues) with a stream of NO_2-free air. NO_2 concentrations can then be varied over the desired range using stainless steel mass flow controllers. Mixtures with pure nitrogen (or even argon) can be used, but with a small loss in accuracy. We recommend using mass flow controllers rated at 1% accuracy and a gas mixture with an accuracy equal to or better than 5%. The user should realize that the overall accuracy of the calibration is, at best, the sum of the accuracy ratings of the mass flow controllers and gas mixture.

When either taking a baseline or calibrating the instrument, wait at least 10 minutes after startup to allow monitor to reach final operating temperature.

At each level of NO_2 concentration, the monitor reading should be allowed to equilibrate until it is constant (30-60 seconds) and then recorded. For highest accuracy and precision, the data should be recorded for a number of samples and averaged. The readings should then be plotted against the known nitrogen dioxide concentration as shown below in Figure 6. (This particular plot was obtained for a range of NO_2 concentrations much higher than normally encountered for the ambient monitoring.) A linear least square fit to the data should be performed. The slope of this fit is the correction to the span value that must be entered into the appropriate place in the monitor software. This value should be very close to 1.0 (± 0.2). Once this data has been stored and saved, the span constant of the monitor will reflect last calibration. Small changes (< 5%) in the span constant will be observed from time to time because of the precision of the calibration procedure and not necessarily because the span constant is actually changing. Any long-term trends in the value of the span constant would indicate that there is either a systematic change in the monitor or that the NO_2/air mixture is deteriorating.

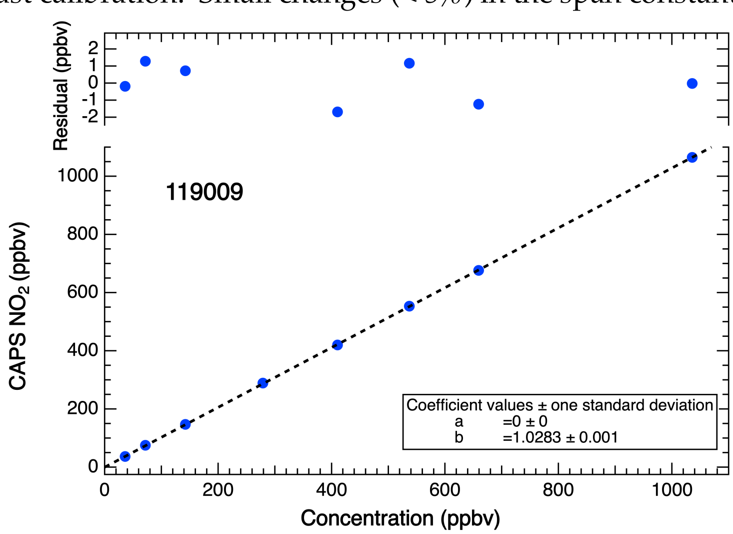


Fig. 6 Calibration plot of monitor readings versus known NO_2 concentration. The slope of the linear least squares fit to the data is also shown.

5. DATA OUTPUT

The current NO_2 concentration reading (with a 3 second time constant) is displayed on the front panel in units of parts per billion by volume (ppbv) or mole fraction. At concentrations below 200 ppbv, the display will provide readings at a tenth of a ppbv resolution, but will revert to 1 ppbv resolution at higher concentrations. It will not provide readings above 2000 ppbv; however, the digital output will continue to operate properly. The display unit is just a digital voltmeter which converts an analog 0-10 V signal generated by the computer to a digital reading. As such, it is prone to offset errors which limits its accuracy.

The true (and most accurate) readings are provided through the RS-232 connection located on the back panel of the monitor. The data are output as an ASCII file organized in the following order:

Time (chosen format), NO_2 concentration (ppbv), Loss(Mm^{-1}), Pressure(Torr), Temperature(K), Signal Level (arbitrary units), Calibration, Status, Last Baseline(Mm^{-1}).

An example of the data stream is show below. This particular example contains a time stamp in hours, minutes and seconds of the day. The data is comma delimited (default setting):

101110,131.413,701.26,758.36,312.60, 400005,1.25,10004,514.09
101111,131.313,701.14,758.27,312.60, 400016,1.25,10004,514.09
101112,131.326,701.14,758.31,312.60, 400010,1.25,10004,514.09

The example provided above indicates that data was being taken between 10:11:10-10:11:12 A.M, the NO_2 concentration was ~131 ppbv, the loss was ~701 Mm^{-1}, and the pressure in the cell was ~758 Torr. The sample temperature was ~313 K, the light signal level was ~400,000. The calibration factor (span value) used was 1.25. The status code (see below) indicates that the monitor pump was on and the system was in its normal monitoring mode and acting as a gas phase absorption monitor at an operating wavelength of 450 nm (i.e., a NO_2 monitor). The last measured baseline reading (with air Rayleigh scattering subtracted) was 514 Mm^{-1}.

Status is a five digit number: abcde

a) Pump and Filter Valve
= 0 Pump Off, No Filter
= 1 Pump On, No Filter
= 2 Pump Off, Filter In
= 3 Pump On, Filter In

In normal operation, only 1 and 3 will appear in the status code

b) Baseline Status
= 0 Normal Operation – No Baseline
= 1 Baseline On- Flush Period
= 2 Baseline On – Measurement Period

c) LED Status
= 0 LED is On
=1 LED is Off (Used only for PM_{SSA} Monitor)

d) Monitor Type

- = 0 NO_2 monitor
- = 1 Gas phase absorption
- = 2 Aerosol Extinction
- = 3 Single Scattering Albedo Monitor
- =4 Multi-cell Monitor

e) Wavelength

- =4 Blue (450 nm)
- =5 Green (530 nm)
- =6 Red (630 nm)
- =7 Far Red (660 nm)
- =8 Near IR (760 nm)

The status number is typically used in subsequent data analysis to determine periods of baseline measurement or other upset conditions.

If the supplied monitor software is used to collect the data, a date and time marker which reflects the host computer date and time is automatically attached to the data as the last column, in addition to those listed above.

If the data are being collected with a user-supplied data acquisition program, it is recommended that all these data be recorded. They are required to reconstruct the data if there is a problem with baseline procedures, calibration, etc. and provide highly useful diagnostic information.

On-Board Data Storage

The monitor automatically stores all data on a memory cache located in the computer stack that operates the monitor. It has the capacity to store approximately several years of data taken with a 1 second sample period. Once the memory is filled, it will begin to overwrite old data files.

In order to access the stored data by ethernet connection, use the ethernet port to connect the monitor either to a network or directly through your computer using a router. Use the supplied DAQ program to identify the IP address assigned to the monitor. Then use your browser with the IP address folowed by a colon and 3000

IP address:3000

Click on the data folder. Clicking on any particular data file will cause the browser to download that file.

Ethernet Access

In order to enable ethernet access to the monitor using DHCP protocol, use the "Instrument Network Configuration" menu item in the DAQ software under the COMMANDS menu. You will be requested to provide a "host name" (the default is just CAPS-serial number) and an IP address will appear in the window if your network recognizes it. This IP address can be used to directly access the monitor via Telnet on Port 9997. At this point in time, we do not yet have a browser initiated version of the DAQ software, although we plan to do so in the future.

System commands are directly accepted over this port. **Therefore, the user should take care in using this option as inadvertently pressing a random key could cause changes in the operation of the monitor**.

6. MAINTENANCE

Particle Filter Replacement

The only regular maintenance required for the CAPS NO_2 monitor is periodic replacement of an in-line particle filter which is contained in a stainless steel housing attached to the inlet inside the monitor. When the loading in the filter becomes too high, there is a substantial pressure drop through the system. This pressure drop can be measured by using the software command to turn off the pump; the difference in pressure with and without the pump is essentially due to the presence of the filter. For the fast response monitor, the pressure drop is ~7-10 Torr with a new filter. Once the pressure drop in the filter reaches ~30 Torr, we recommend that the filter element be replaced. If this event occurs frequently, an external particle filter (compatible with NO_2 and with minimal pressure drop) should be employed to maximize the ease of filter changing.

To replace the filter element, undo the Swagelock connection to the filter housing marked **OUT**. Unscrew the hexagonal flange at that end. It is sealed with an o-ring. Pull out the filter using a pair of tweezers and replace with a new element. Screw the flange back in and snug, taking care not to snag the o-ring on a screw thread. Reseal the Swagelock connection again taking care not to over-tighten. Each monitor comes with a box of 10 replacement filters. Once this supply are used up, you can buy the elements directly from a supplier.

Disposable Filter Element:	12-32-60K
Disposable Plastic Filter:	DIF-BK60 (Kynar housing is preferable to Nylon housing for NO_2)

available from United Filtration Systems (http://www.unitedfiltration.com).
equivalent units available from Parker Balston and other suppliers

Scrubber Module Replacement (for monitors with internal scrubber capacity)

Aerodyne will provide an exchange program for the reusable scrubber modules. When the scrubber unit has reached the end of its lifetime, remove the unit from the system and ship it back to Aerodyne which will in turn send a new unit module. If the user so wishes, he/she can purchase its own supply of Purafil and refill the module on his/her own.

Mirror Contamination

With proper operation of the monitor, the mirrors should never become substantially contaminated. However, this can occur because of a pressure upset or some other event. However, these monitors can operate within specification even if the mirrors become somewhat dirty. Contaminated mirrors cause a loss of signal and thus decrease in the sensitivity. However, this will not change the calibration of the monitor. If the monitor noise increases substantially, one should check the measured optical loss (listed on the display and in the data files). Upon shipping, this value should be around 500 Mm^{-1}; substantial loss of sensitivity probably would not be noticed until the loss approaches 1000 Mm^{-1}.

The mirrors are readily cleaned. Their coatings are relatively robust and should be treated just as one would treat any multi-layer optical film. Initially, gloves can be employed when handling the mirrors to avoid contamination. However, with practice, these are readily dispensed with.

Required Supplies

1. High quality lens tissue (we recommend ThorLabs)
2. Spectroscopic or HPLC-grade methanol and acetone
3. Clean **glass** bottles with **glass** eyedroppers
4. Supply of particle-free air or Aeroduster
5. A means of holding the 1" mirrors in place while cleaning – a plastic or Teflon block with a shallow wedge or cylinder with appropriate shoulder will work well. [CRD Optics sells inexpensive blocks suitable for this purpose. (http://www.crd-optics.com/crd-blocks.html)]

Uncoupling of Detector Module from Sample Cell

1. Shut down monitor, remove power cord and take off monitor case cover using supplied Allen wrench (5/64"). Screws are 6-32 (3/8" long).
2. Use 7/16" nut driver to loosen clamp nearest sample cell on Detector Module.
3. Slide detector module off the cell and rest on floor of monitor.

Removal of Cell from Monitor

1. Disconnect the Swagelock fittings (i.e., a tee) attached to the sample cell.
2. Unplug connector on the wires coming out of the back of the cell from printed circuit board located on baseplate.
3. Unscrew the four (8-32) screws holding the cell in its holder and remove top cover.
4. Remove cell from holder.

Removal of Mirrors from Cell

1. Starting at one end, unscrew optics holder, making sure to keep cell upright.
2. Remove o-ring from mirror using tweezers – o-ring might be attached to insider of optics holder. Do not misplace o-ring as it is required for proper operation of monitor.
3. Turn cell upside down and allow mirror to drop out of cell. Some tapping of cell might be required. **Remove, clean and replace one mirror at a time. The mirrors work better when kept at original end of cell.**

Cleaning of Mirrors

1. In a reasonably particle-free environment, place mirror on holding block with curved side of mirror up. The curved side will have a circular mark near the mirror edge.
2. Put the near edge of a single lens paper sheet on the mirror and allow 1-2 drops of solvent to fall on paper. (Do not overwet!! This is a beginner's mistake.)
3. When the mirror becomes fully wetted, draw the lens paper along mirror towards you. Repeat multiple times, first with acetone and then with methanol. With practice, one sheet of lens tissue can be used to make 3 different swipes. We recommend making at least 6 swipes with acetone and 6 with methanol.
4. Use dry air or emission from Aeroduster to remove any excess solvent.

Replacement of Mirrors in Cell

1. Place curved side of mirror into one end of cell, making sure that it is securely seated.
2. Replace o-ring on back surface of mirror.
3. Screw optics holders onto cell. They should be screwed on firmly but not over-tightened – the threads can be damaged.
4. Repeat with other mirror.

Putting the Cell Into the Monitor

1. Reattach detector block, being careful to tighten fittings.
2. Place sample cell in mounting block.
3. Reconnect LED power cable to printed circuit board mounted on baseplate.
4. Put back cover with screws.
5. Slide detector module back onto lens/mirror holder and tighten clamp nut with driver.
6. Reconnect Swagelock fittings.

Note on mirror cleaning

Learning to clean mirrors takes practice and patience. If you attempt to clean the mirrors and the results are worse than before or if they do not improve, just keep trying. Make sure that there is no lint or other particulate contamination on the mirror surface. A single visible particle is sufficient to cause substantial optical loss. Avoid performing this operation in high relative humidity environments as the evaporation of solvents can cause liquid water condensation on the mirrors.

Cell Maintenance

If the cell itself becomes contaminated, simply clean it in an ultrasonic cleaner with dishwashing detergent or other mild soap or detergent, rinse with water and then with methanol. Allow to dry thoroughly. Do not attempt to clean the inside of the cell with a brush or other device. The surface on which the mirrors rests contains an easily damaged knife-edge which controls the alignment of the mirrors. If damaged, the cell must be replaced.

7. SOFTWARE COMMANDS

The following software commands are provided for those who want to control the monitor using their own software. These instructions can also be used with a terminal communications program such as Hyperterminal. Commands are entered as ASCII characters over the RS-232 or USB connection. < > denotes a keystroke which is not a simple letter and _ denotes a space.

General Information

All letter commands end with <cr> or <lf>. (Note that <cr> here means 0x0D; <lf> means (0x0A)) Some commands take 1 or 2 integer arguments, and where used, they are separated from the command, and from each other, by at least 1 space. While taking data, these commands take effect at the conclusion of each observation except during baseline operation when no communication with the monitor is allowed. Thus, if data is being sampled at 10 seconds, it can take that long for the command to take effect. If a baseline period is operative, the command will be ignored.

Commands

Command	*Argument*	*Function*
<bs>		Delete Last Character
?		Ping; causes immediate return of ! character (0x21) in reply
D	mm/dd/yyyy	set date
E		Return Setup Table
F/f		Operate valves (F=filter In; f= filter out)
G		Restarts Data Acquisition after Q command
H/h		Enable/disable Automatic Baselines
I		system status (integer divisors, mod and IF, actual integration time)
Q		Stops Data Acquisition
T	hh:mm:ss	Set monitor clock (24 hour time required)
V/v		Turn on/off pump
Z		Start Baseline Measurement Mode